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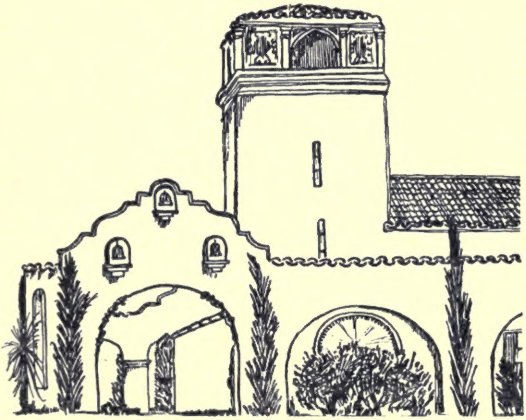

OXFORD MEDICAL PUBLICATIONS

ORTHOPÆDIC SURGERY OF INJURIES

PUBLISHED BY THE JOINT COMMITTEE OF
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OXFORD MEDICAL PUBLICATIONS

ORTHOPÆDIC SURGERY OF INJURIES

BY VARIOUS AUTHORS

EDITED BY

SIR ROBERT JONES, K.B.E., C.B., F.R.C.S.

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HON. ADVISER TO THE MINISTRY OF PENSIONS (ORTHOPÆDIC SURGERY)

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FOREWORD

PROBABLY one of the most striking features in Surgical Science during the present war has been the enormous development of orthopædic surgery.

Never before has the need for increased knowledge and perfection of technique been so keenly felt; the war has, unfortunately, created an enormous influx of mutilated soldiers, and the duty of restoring these men, by every means possible, from a crippled condition to a state in which they may be useful and happy members of the nation has devolved on the surgical profession.

Orthopædic surgery has developed and expanded by rapidly increasing strides, and now embraces a scope and range undreamed of in pre-war days. Appliances for restoration of function and for re-education have also been improved to a marvellous extent, and still further improvements may be looked for in the future.

There is—or should be—no sharply defined demarcation between general and orthopædic surgery. The general surgeon must have a knowledge of orthopædic surgery in order that the best possible after-results of his operative procedures may be obtained. The whole subject is, from both the national and military points of view, increasing in importance every day, and the necessity for a further scientific knowledge regarding the many problems which have arisen and will still arise is increasingly felt. During the last four years Sir Robert Jones has devoted his skill and knowledge to the service of the army, and in publishing this book he has added one more to the list of valuable services for which we are already indebted to him.

T. H. J. GOODWIN, D.G.

January, 1921.

EDITOR'S PREFACE

IN editing a work, written by my own colleagues attached to what we first called Orthopædic Centres, but later changed to Special Military Surgical Hospitals, it is necessary to make a few preliminary remarks. The term 'orthopædic', if we adhered to its etymological meaning, would cover only a small field of its practice even in pre-war days, and less still when we consider that it assumed in time of war. It has enlarged its borders chiefly on the operative side by reason of the advances made in pathological, anatomical, and physiological knowledge which have rendered it possible to perform operations leading to the restoration of physical function which years ago seemed quite impossible. There is no definite operation which is essentially orthopædic; there is no special splint, simple or complex, which bears the peculiar mark of the orthopædic surgeon. Orthopædic surgery is based on, and consists of, the recognition and practice of definite principles of treatment, whether operative, manipulative, or educational, which lead to the restoration of function in nerves and muscles and in deformed or disabled limbs. This, in itself, is very inclusive, covering as it does so large a field of surgery. The orthopædic mind is trained to think in terms of function. The operative stage for which the surgeon should be fully equipped, although essential, has only its proportional value. He has even more largely to deal with a pre-operative and a post-operative stage. Such operations as he is called upon to perform are often only the necessary preliminaries to re-education and the restoration of function which includes the correction of gross deformities, the reconstruction of joints, grafting operations on bones, muscles, and tendons, and the repair of injuries due to the severance of nerves. It teaches us to maintain joints and limbs in the proper

position so that the injured tissues may recover functional efficiency. This is preventive treatment. It involves also the correction of faulty positions of joints by carefully conducted manipulations, and the prevention of those pathological displacements which so often accompany acute arthritis.

At the beginning of the war, when the wounded poured into this country as a result of great casualties and rapid evacuations in France, our hospitals all over the land were filled to overflowing. In spite of every effort to meet this rush, cases could not be retained sufficiently long in our central hospitals to secure all the help that was needed ; and, as a consequence, our auxiliary hospitals and command dépôts were occupied with cases which really required very skilled treatment. Meanwhile, the exigencies of war demanded so large a proportion of young skilled surgeons for service abroad, that even our large teaching hospitals were considerably understaffed. In these circumstances it can readily be understood in what need the country stood for hospitals where evacuation could be delayed and treatment of an intensive kind practised. A visit to auxiliary hospitals and command dépôts was undertaken in order to find out the types of cases most urgently requiring attention. Segregated in these establishments we found large numbers of men with undiagnosed nerve lesions ; ununited and malunited fractures ; joints ankylosed in positions which rendered the limbs useless from the point of view of function ; excisions which had resulted in flail joints, and stiff joints with inflammatory symptoms which were undergoing massage and movements. The most striking type of case was the neurological. Patients were being massaged where divided nerves had not been sutured. Functional cases, which are so readily re-educated and cured, were generally classed as malingerers. In addition to all this, numbers of instances were noted where, after operations, most excellently performed, a want of appropriate after-treatment rendered them either useless or of little benefit to the patient. This state of affairs was not due to negligence on the part of the

medical officers, who generally proved extremely anxious to learn and were hard working; but they were overworked, and did not possess the necessary training to enable them to treat such cases. In addition, the equipment for this type of surgery was often deficient. As an instance one may mention the after-treatment of tendon transplantation. In the early days of fighting, from experience gained in pre-war days I recommended and described an operation for transplanting flexor tendons in irreparable damage to the musculo-spiral and post-interosseous nerves. With good technique and appropriate after-treatment an admirable result could be safely predicted. Failure, however, proved inevitable when the operation was performed and the patient evacuated without provision of skilled after-treatment.

The War Office then decided that an effort should be made to segregate groups of cases into especially staffed and equipped centres, where continuity of treatment could be secured for such cases as injuries to peripheral nerves, ununited and mal-united fractures, injuries to joints, and cases likely to result in deformities of the extremities. At a later date, recent fractures of the femur were included. The central idea which dominated the scheme was that under one roof every therapeutic department should be represented, and that each number of the staff should be allotted the work for which he was best suited. Each centre consisted of men experienced in general surgery, of a neurologist, of young men with orthopædic training, and of special departments such as massage, muscle re-education, electro-therapy, hydro-therapy, physical exercise, and curative workshops. The special orthopædic staffs were mainly composed of the younger generation of surgeon with minds sufficiently flexible to grasp new ideas, and with sufficient energy to bear the physical strain which orthopædic work involves. We began with 250 beds, and continued until we nearly reached 30,000. A large proportion of cases admitted had already undergone treatment which generally involved a series of operations, and the patients were apt to be depressed and often

rebellious. We endeavoured, therefore, to render the hospitals as cheery as we could. Great sympathy and patience were exhibited by the staffs, and gentle methods of persuasion took the place of military command. The cured comrade added his persuasion, and the men began to show a growing spirit of trust. Then came the direct benefit, both mental and physical, derived from the curative workshops. We are deeply indebted to His Majesty, King Manuel, who has graciously contributed an article on the curative workshop. He created it, and for two years devoted the better part of each day to organizing and superintending the work. Without his help our efforts would have sadly lacked fruition.

The governing principle in regard to curative work is founded on the knowledge that voluntary movements are of much more value than passive movements. Voluntary movement in one of its various forms has a direct curative effect upon the muscular structure. Mechanical movements, such as those produced by Zander machines or other agencies, are usually passive in character, and are governed by the machine rather than the patient's mind. The exercises practised in the curative workshop are of two kinds—the direct and the indirect. The direct work has often to be specially devised—a screwdriver may be employed to supinate the arm, a saw to exercise the elbow, painting to move the shoulder—but with an ingenious instructor, special ways of holding instruments are constantly devised in order to directly affect the joint involved. The indirect method of attack is often employed. For example, when a man with a stiff ankle is set to plane or saw wood, he unconsciously uses the ankle as he gets interested in the work which his hand is doing. Periods of physical work are varied by instruction in the principles of the craft in which he is engaged. It adds to the interest, rests the joints, and, in addition, is a useful equipment. From the psychological standpoint it is found better to secure the man's productive occupational treatment than to give him a mere exercise with tools. An ingenious tutor can generally manage

to devise an occupation which will combine appropriate movement with production. The curative workshop does not supplant the massage department or the gymnasium, but it ensures the patient prolonged exercise of an active and interesting kind.

The treatment of fractures of the femur during the early part of the war, both at home and abroad, left very much to be desired. Team work, continuity of treatment, and segregation in special hospitals did much to improve results. The introduction of the Thomas splint to the advanced units, and the training of the orderlies in its application lessened shock and saved numberless lives. The surgeons at the base hospitals for fractures developed excellent methods, so that injuries which, at the beginning of the war, were followed by shortening and deformity, soon resulted in excellent recovery. At the Orthopædic Centres at one period we had five hundred compound fractures of the femur, yielding an average shortening of less than half an inch, and in none of these cases was internal splinting resorted to.

The contributions to this volume will help to prove how necessary it is that a thorough knowledge of general surgery should be possessed by any surgeon who practises a special branch. Nothing is more fatal to progress than when from defect of general surgical training a specialist is limited to one view of a subject. When a firm surgical foundation is acquired he can deflect his energies with great advantage to special fields. Unless this be accepted as a cardinal principle, orthopædic surgery may even yet be reduced to a refuge for any one who is unable to hold his own in any operative procedure which his art requires of him. The orthopædic surgeon should be governed by sound surgical principles and not become entangled in detail. Function is his goal and he should know, and be able to practise, the best way of obtaining it. The operation means to him only the beginning of his problem, and his most brilliant operative exploit, unless directed to a functional success, should be a reproach.

I desire to express a deep debt of gratitude to the American Government for the loan of twenty-five well-trained orthopædic surgeons for the period of the war. Their services were invaluable and badly needed. My thanks are extended also to my friends, Colonel Goldthwait and Major Osgood of Boston, who considerably lightened my labours. The ever-ready help afforded to the equipment of our centres by the Honourable Sir Arthur Stanley and Sir Robert Hudson, the Chairman and Treasurer respectively of the British Red Cross Society and the Order of St. John of Jerusalem, materially added to their efficiency. I am also grateful to Major Rowley Bristow for his help in revising manuscript.

In conclusion, I desire to place on record my sense of gratitude to my loyal friends and workers, both American and British. They proved a constant source of joy and inspiration.

ROBERT JONES.

LIVERPOOL,
January 1921.

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VOLUME I

THE PRINCIPLES AND PRACTICE OF HUGH OWEN THOMAS

BY

ARTHUR KEITH

Conservator of the Museum and Hunterian Professor Royal College of Surgeons, England

THE PRINCIPLES AND PRACTICE OF HUGH OWEN THOMAS

SUMMARY OF THE LIFE OF HUGH OWEN THOMAS

Hugh Owen Thomas was born when his mother was on a visit to her people at Bodedern, Anglesey, August 23, 1834. *Her husband, Evan Thomas, was also a native of Anglesey, where his forefathers for many generations had practised as bone-setters. At the time of Hugh's birth his father had established his home in Liverpool, where his fame as a bone-setter had already spread beyond the confines of the city. Hugh was a delicate child and, on account of his health, was brought up in the country, attending school in Anglesey, St. Asaph, and afterwards, when he lived at home, Dr. Poggi's school, in New Brighton. His professional career may be divided into the three following stages:*

FIG. 1.—HUGH OWEN THOMAS, from a photograph taken when he was in his fortieth year. He died on January 6, 1891, in his fifty-seventh year.

I. APPRENTICESHIP AND STUDENTSHIP—*from* 1851, *when he went at the age of seventeen as apprentice to his uncle Dr. Owen Roberts of St. Asaph, until* 1858, *when he 'returned from a short period of study' in Paris to commence the practice of Medicine in Liverpool at the age of twenty-four.*

Of these seven years, four were spent with his uncle, two at the University of Edinburgh and one at University College, London, and in Paris.

II. A period of PRACTICE AND OBSERVATION *extending from* 1858,[1] *when he joined his father in Liverpool, until* 1875, *when, at the instigation of Professor Rushton Parker, he commenced to publish his observations. The partnership with his father—a skilful but moody man—at* 72 *Great Crosshall Street, lasted scarcely a year; in* 1859 *H. O. Thomas made his home at* 32 *Hardy Street, in* 1870 *moving to a house close by—No.* 11 *Nelson Street, his home until his death. In an adjacent house he established his hospital and set up his workshops. Thus his life was spent in the most central and busiest quarter of Liverpool. In* 1864, *at the age of thirty, he made a happy marriage, but had no children.*

III. A period of PRACTICE AND PUBLICATION*—extending from* 1875, *when he was forty-one, until January* 6, 1891, *when he died early in his fifty-seventh year. A list of his chief publications is appended, compiled according to the date at which they were issued. In publication, as in every affair of his busy life, he set convention aside and followed his own judgement or fancy. He employed his own printer and, at first, acted as his own publisher. The high-wheeled phæton, in which he drove a pair of black horses, was of his own design; so was the nautical peaked cap he wore to shade his eyes; so were the medical theories he evolved and the surgical appliances he invented. He was a thin, dark, fragile-looking man, well under medium height—*5 *ft.* 3 *or* 5 *ft.* 4 *in., but of indomitable spirit and of unbounded power of application. His profession was his hobby and in his hobby he included the art of healing in its widest scope.*

LIST OF HUGH OWEN THOMAS'S CHIEF PUBLICATIONS

1875. *Diseases of the Hip, Knee, and Ankle Joints, with their Deformities: Treated by a new and efficient method* (with Introduction by Professor Rushton Parker). 1st Edition, 1875; 2nd Edition, Liverpool, 1876, pp. 283, 26 pls.; 3rd Edition, 1878.

1878. *A Review of the Past and Present Treatment of Disease in the Hip, Knee, and Ankle Joints*, 1878. pp. 66.

1881. *The Treatment of Fractures of the Lower Jaw.* pp. 13. 5 pls. (Part V of *Contributions to Medicine and Surgery*.)

1883. *Intestinal Disease and Obstruction* (Part I, *Contributions*). pp. 284 and xvi (appendix). 5 pls.

1883. *Nerve Inhibition and its Relation to the Practice of Medicine* (Part VIII, *Contributions*). pp. 47.

1883. *Principles of the Treatment of Diseased Joints* (Part II, *Contributions*). pp. 151.

1885. *The Collegian of* 1666 *and the Collegians of* 1885, *or 'What is Recognized Treatment?'* (Part IV, *Contributions*). pp. 147. 1st Edition, 1885; 2nd Edition, 1888.

[1] In this year the Medical Register for British Practitioners was established by Act of Parliament.

1886. *The Principles of the Treatment of Fractures and Dislocations* (Part VI, *Contributions*). pp. 104. pls. 17.

1887. *Fractures, Dislocations and Diseases and Deformities of the Bones of the Trunk and Upper Extremities* (Part III, *Contributions*). pp. 127. pls. 16.

1888. A New Lithotomy Operation. *Provincial Med. Journ.*, April, 1888.

1889. *An Argument with the Censor at St. Luke's Hospital, New York* (Part VIII, *Contributions*). pp. 45.

1890. *Lithotomy* (Part VIII, *Contributions*). pp. 16.

1890. *Fractures, Dislocations, Deformities and Diseases of the Lower Extremities* (Part VII, *Contributions*). pp. 320. 117 figs.

Spinal Deformities, projected in 1878 as Part IX of *Contributions* (never published).

Manual of Orthopædic Surgery, announced in 1878 as shortly to be published. Never published.

It was the custom of John Hunter to prescribe ' Rest ' as a routine measure in the treatment of disablements of the motor system of the human body. After him came John Hilton, who regarded ' Rest ' as the most powerful aid which the surgeon could bring to the aid of disordered tissues. Hilton elaborated the means of securing ' Rest ' into a system ; but the man whose principles and practice we are to describe made ' Rest ' his Creed and Ritual. Hugh Owen Thomas believed that an overdose of rest was impossible. To use the expression which he never tired of repeating—Rest must be ' enforced, uninterrupted and prolonged '. I had selected the names of these three men in the above order because they appeared in British surgery at successive periods : Hunter 1728–93, Hilton 1807–78, Hugh Owen Thomas 1834–91 ; with each successive man and period ' Rest ' became more urgently advocated, as the best means of assisting the natural powers of repair to overcome the violence done by disease or injury. It was only when I came to arrange the matter of this article that I saw that our chosen advocates of ' Rest ' had been drawn into the service of surgery from three diverse racial elements of our British population. Hunter was a Lowland west-country Scot, but if his physical appearances do not belie him, he had more than a mere strain of Highland breeding in him ; Hilton was a sturdy Saxon, strong, overbearing, made to rough-shoulder his way through the world. H. O. Thomas was a pure product of North Wales. He was born in Anglesey of a long ancestral line which had handed on the art of bone-setting from father to son. He spent his early boyhood in North Wales, and in 1851, at the age of seventeen, he was apprenticed to his uncle, Dr. Owen Roberts of St. Asaph. He had the imaginative temperament, so common amongst his countrymen, and masked a nervous and retiring disposition by a somewhat brusque manner.[1]

[1] I take this opportunity of thanking Professor Rushton Parker, Sir Robert Jones, Sir Vincent Evans, Mr. Lynn Thomas, and Dr. Dawson Williams for their liberality in supplying me with information relating to Mr. Thomas's earlier life.

Men could not have approached a common objective by more diverse routes than did Hunter and Hilton on the one hand, and H. O. Thomas on the other. There was no prolonged and laborious apprenticeship in the dissecting and post-mortem rooms for him, no appointment to the staff of a great teaching hospital, with the commanding position, affluence, and social status which such appointments can and do bring to ambitious men. Thomas we shall find is a plain man, guarding jealously his simple manners and homely Liverpool life, with more than a shade of contempt in his speech and deportment towards the men who sought to borrow authority from their official status and worldly position. Hunter and Hilton worked long and hard in the dissecting and post-mortem rooms in the search of facts to guide them in formulating rational means of treatment ; they observed the efficacy of their methods in regulated hospital wards and on closely tended private patients. The circumstances amidst which Thomas matured his experience were very different ; his field of observation was the steady stream of accident cases which poured into his surgery from the dock-land of Liverpool. His field of experiment lay in his upper workroom, where, in workman's attire, and with the hand of an expert, he wrought the exact form of splint of machine which he desired for the treatment of each particular case which came under his care. Here, then, is a surgeon of a new kind, one who could and did use his knife, but it was his final and fixed opinion, founded on thirty-three years crowded with experiments on orthopædic cases, that the blacksmith's hammer, deftly used, was, in most cases, a more powerful reparative instrument than the surgeon's knife.

Hunter and Hilton never ceased gathering observations on the condition of parts as revealed in the dissecting and post-mortem rooms ; they kept adding to their own stock and to the world's stock of knowledge. But you will search the many writings of Hugh Owen Thomas and fail to find a single observation made by him on the state of parts seen at operation or after death ; not a glimpse of the disordered state which it is the surgeon's task to bring back to a healthy condition. It is true that Thomas never did study those conditions in the post-mortem room, dissecting room, or experimental laboratory, but there never was a man who studied more persistently and observed more closely the manifestations of disease and injury as seen in the living state. For him surgery was an experimental science ; each case was an experiment to be studied, diagnosed, explained, treated, and the results of such treatment to be carefully recorded. ' There is an opinion prevalent,' he noted, ' that only

For an appreciation of H. O. Thomas as an Orthopædic Surgeon see articles by Dr. W. Colin MacKenzie, *B. M. J.*, 1917, p. 669, and by Mr. Lynn Thomas, C.B., F.R.C.P., *B. M. J.*, July 15, 1916.

gentlemen on the staff of our public charities can treat, with any chance of success, disease of the hip-joint, and certainly hitherto, they have advantages not possessed by the general practitioner.' But he was also aware, as Sir James Mackenzie has persistently pointed out, that the general practitioner has opportunities from which the staff-surgeon is debarred ; he sees a case in its initial stage, he takes it under his personal supervision, and can often follow its progress to the end. Thomas, too, lived in the midst of one of the world's biggest industrial battlefields ; the limits of his practice lay along the shores of the seven seas, for seldom a week passed without bringing him some derelict case of accident. It was Hugh Owen Thomas's great merit to have proved that a busy general practitioner can, by purely clinical methods, win for himself a permanent place among the benefactors of medicine.

Having thus broadly defined Thomas's place amongst surgeons, it is now necessary for us to trace him through the earlier years of his professional life and watch the development of his principles and practice. He was born and bred an orthopædic surgeon. His father, Evan Thomas, had his home and surgery, so Professor Rushton Parker has informed me, in 72 Great Crosshall Street,[1] Liverpool, where, although unqualified, he was the referee of certain workmen's clubs—dock gatesmen, ships' carpenters, boilermakers, and several others—the members having unbounded faith in his treatment of injuries of all kinds. He had five sons, all of whom became qualified surgeons; Hugh Owen was the eldest.[2] As the boys grew up they had to help in the surgery in Great Crosshall Street, and could not fail to gain a first-hand knowledge of injury and disease. Indeed, it was proposed at one time that Hugh should become his father's apprentice, but the ill state of his health—he never at any period of his life was robust—led to a change of plan, and in 1851, at the age of seventeen, he was apprenticed to his maternal uncle, Dr. Owen Roberts of St. Asaph, twenty-five miles from Liverpool as the crow flies. His apprenticeship lasted for four years. In 1855, at the age of twenty-one, he went to Edinburgh to study medicine. Syme and Spence and Simpson were in the heyday of their fame; Goodsir was teaching anatomy; there was then a demonstrator of anatomy newly arrived from London—William Turner. Lister was also there commencing the Edinburgh phase of his great career. But in Thomas's writings there is never an allusion to his life in Edinburgh ; only one man seems to have impressed him. Hughes Bennett. He apparently spent two winter sessions in Edinburgh,

[1] Later, he had his home at Seacombe on the south bank of the Mersey, but retained his surgery in the small house in Great Crosshall Street.

[2] Mr. Evan Thomas still lives and practises in his father's old home, 72 Great Crosshall Street. He was born in 1838—four years after his celebrated brother, Hugh. (Rushton Parker.)

and in 1857 he attended classes at University College, London ; of his life and experience in London he never gives us the slightest hint in his writings. In 1857, in his twenty-third year, he became a member of the Royal College of Surgeons of England, and then proceeded to watch the practice of French surgeons in the hospitals of Paris. In the spring of 1858, the year which saw the Medical Register established in Great Britain and Ireland, he returned to Liverpool to help his father in the Great Crosshall Street surgery. Of what he saw and learned in that surgery during his boyhood, in the vacation periods of his apprenticeship and student days, and now during the short year he was to spend in his father's practice as a qualified practitioner—for before twelve months were finished father and son were separated—he gives us several interesting and instructive glimpses :

Many cases have I observed enter the consultant's surgery, lame and in pain, who after being well fitted with a layer of stiff adhesive plaster, over and around the affected articulation, left the surgery less lame, and in less pain ; sometimes even, without pain. This is the history of some ; others indeed had a different termination. (*Review of Past and Present Treatment,* 1878.)

For many years I was a witness of the treatment of joint disease by methods sometimes purely expectant, at other times consisting of a fractional fixation, and the results in some instances were certainly so striking as to excite my envy. But these very cases I now know, would have recovered, some with no attention and others with but imperfect rest. For one result which excited my admiration, ten failed. What is wanted is a method which will benefit all cases. (*Review of Past and Present Treatment,* 1878.)

I watched for many years the extensive practice of an untrained gentleman and, to do him justice, record here that he never failed to secure a perfect restoration of these fractures (of lower end of radius) and if I were to say I observed his treatment of two hundred cases, I should be vastly underestimating their number ; yet his treatment, guileless of anatomy, was only thorough reduction and reasonably applied counter-pressure. . . . He was equally successful in his management of fractures of the lower end of the tibia up to the period of use, when, from his not taking precaution to centralize the weight of the body on the foot, several of his cases would lapse into deformity. (*Contributions to Surgery and Medicine,* pt. iii, 1887.)

These extracts show us that when he left his father and set up for himself in 32 Hardy Street in 1859, he had already acquired an extensive and very practical knowledge of a difficult class of surgical cases—a knowledge which was being checked and criticized under the light of the medical experience gained in Edinburgh, London, and Paris. It is but a short distance from Great Crosshall Street to Hardy Street, and most of the club appointments, worth about £500 per annum, which had been held by his father, followed him to his new home. He had no waiting

period; he started away with an assured practice. We have to watch him commence his life's work there if we are to understand what he succeeded in accomplishing in the thirty-two busy years which are to follow. He is up early in the morning—at 5.30; before breakfast at eight, he has already made a round among his patients; he is in his surgery from nine to one; he has an afternoon round, an evening spell in his surgery, and again another late round of visits. He follows the progress of his cases very closely; they are his hobby. He already has a theory or principle which he is applying with all the might and ingenuity of which he is capable. He rarely mentioned Hunter in his writings, but the principle he is to apply—even the language in which he couches that principle is truly Hunterian. The following extract is his statement of the principle which guided him:

If any person, with a part diseased, possesses sufficient vitality so that there be a tendency to reparation in the diseased locality, then Nature always has a mode of operation, and in very many instances the natural method of restoration has become known to us. Indeed the practice of medicine and surgery mainly consists of either aiding or controlling or supplementing this natural effort to resolution. (*Contributions*, pt. iii, 1883, p. 7.)

It is clear then, when Thomas set out from 32 Hardy Street to sail the sea of practice, he already realized that he could not cause the tides or raise the winds that brought derelict human ships to the harbour of resolution; he realized that the utmost he could do, was to steer in such a way that the best use was made of such tides and winds that came along. Even at the end of thirty-two years of incessant observation, as the following extract will show, he was often in doubt as to how far a happy issue was owing to his seamanship, or how far it depended on the fortune of the elements:

As in Medicine, so in Surgery, even a discerning practitioner often finds it difficult to satisfy himself whether the patient got well with his assistance or despite his interference. (1890.)

In Hardy Street he lived for eleven years; there he married and prospered in spite of ill-health, overwork, and overstudy, and in 1870 at the age of thirty-four moved to a house close by—11 Nelson Street, which his nephew, Sir Robert Jones, still occupies. There he held his Sunday clinics. 'When the bells were tolling for church, the surgery at Nelson Street was filling with a congregation of suffering folk.' Thus he lived from his twenty-fourth to his fortieth year, from 1858 until 1874, his fame during that period being still confined to dockland. In 1874 an event occurred which led to his labours becoming better known. Mr. Parker, a police surgeon, had reason to visit Mr. Thomas, who then had his surgery and hospital in Nelson Street, in connexion with a case—

that of an inspector of police—who was then under Mr. Thomas's care, on account of a compound fracture of the leg. Mr. Parker had taken with him his son, Rushton, a young surgeon of twenty-eight, with an assured future in the Liverpool School of Medicine. We can learn the effect of that visit from the preface which Thomas wrote for his first important publication on *Diseases of the Hip, Knee, and Ankle Joints, with their Deformities: Treated by a new and efficient method.* 'I saw at once', writes Professor Rushton Parker, 'that here was a master and the acquaintance ripened quickly into friendship, I insisting on his publishing immediately, an account of his hip and knee splints, because, I said, "these are things I must use, teach and publish, and there are men in this town who will palm them off as their own if they get to use them intelligently".'

That was Thomas's first important publication, but not actually the first. In 1867 he had published a short paper in the *Lancet* on the treatment of ununited fractures, and in 1873 described a method of using silver wire ligatures for the treatment of compound fractures of the mandible. The ligatures were fixed by a terminal spiral which could be conveniently tightened as the mandibular fragments yielded and came together. He also advocated then a practice, adopted in the present war, of removing any tooth situated on the line of fracture, as its presence was always a cause of retarded union. Once started as a writer he continued to issue *Contributions to Surgery and Medicine* almost annually until death brought an end to a career, handicapped by indifferent health and overtaxed with work. He died in 1891 at the age of fifty-six. Even in the manner of publication he emphasized his individuality. His writings were issued in pamphlet form, designed, one would almost think, for a temporary and private circulation; but time will show that they have a permanent value for thoughtful medical men. He liked to reprint, at the end of each Contribution, the press notices and strictures which had greeted its first appearance. On very few occasions did the critics recognize their merits or extend a welcome to them. It is because of the means he adopted for publication that his numerous writings are so little known; it is very difficult now to obtain a complete set of Hugh Owen Thomas's Works.[1]

He based his methods of treatment on the axiomatic belief which had served to guide Hunter and Hilton, viz. that the power of repair is an inherent property of living tissues. 'The crying evil of our art in these times [1883]', he writes, 'is the fact that much of our surgery is too

[1] 'The printer, a quaint character, whose name was Dobb, lived in a small shop in Gill Street. He was factotum and publisher, although in the later editions the name of H. K. Lewis appears on the covers. Very few were sold, and the remainder occupied a large room in Mr. Thomas's house in Nelson Street.' (Sir Robert Jones, 1913.) See list of publications at commencement of this chapter.

mechanical, our medical practice too chemical, and there is a hankering to interfere, which thwarts the inherent tendency to recovery possessed by all persons not actually dying.' Farther on, in another passage, he adds: 'There are actions which Nature cannot do so well as the artist in charge.' He held that in only one way could the surgeon aid the reparative property of injured or diseased tissues to come into full operation, and that was by giving the part rest. His message to the surgeons of his time was that they did not understand the meaning of the word 'rest'. Hilton, he said, fixed a limb in a splint and believed he had given it rest. Immobilization he held to be the first requisite, but it must be applied in such a way that the diseased part was not compressed nor the normal circulation of the limb in any way interfered with. All forms of plaster-splint necessarily exert an injurious pressure, and for that reason and several others he abandoned them at an early stage of his practice. Pressure he held was a form of restlessness or irritation. If he applied a stiff or elastic bandage to a diseased knee-joint so as to surround and compress it, he held that in so far as he lessened the movement of the joint he assisted repair, but in so far as he compressed it, he hindered repair. He distinguished such a form of immobilization as that of 'direct fixation'; his ideal form of immobilization was that of 'indirect fixation', which is best illustrated by his knee-splint. He designed this splint so that it could prevent movement at the knee and yet leave the joint not compressed and the circulation of the limb unhindered. All forms of immobilization which depended on traction by weights, pulleys, or elasticity he discarded not only because they transgressed his conception of rest, but also because in practice he found them less effective than that of 'indirect fixation'. Rest had to be continued without interruption until all trace of unsoundness had disappeared from the joint, and then that point being reached the cure would be completed by the gradual return of natural voluntary movements. Therein lies the essential doctrine Thomas came to preach to the surgeons of his time.

If I were to cite an instance to illustrate his conception of 'Rest' and the manner in which his methods of treatment differed from those of all the men who had gone before him, I should select it, not from his papers on fractures and diseases of joints, but from one he regarded as of great, and of lasting merit, one in which he describes the best means of treating cases of obstruction of the bowel. In his time, such cases were usually treated by active measures, by purges, enemata, kneading, and movements; as a last resort enterotomy was performed. He had followed the various endings of cases of acute obstruction of the bowel during his apprentice days at St. Asaph, and at a later date began to apply his treatment of rest with a success which led him in 1875 to write his first paper on this subject. It was not, however, until 1884,

when the treatment of such conditions became a subject of discussion at the Liverpool Medical Institution, and afterwards of an acrimonious correspondence in which Sir Mitchell Banks was involved, that this part of his labours received public attention. In his treatment of such cases we obtain a concrete illustration of what he means by 'Rest'. The treatment of the case I have selected for an example has been placed on record by his nephew Sir Robert Jones.[1]

I remember well how Mr. Thomas called the relatives together and told them he was going to make a fight for the patient's life. He urged them to be loyal and to help him, and, to add to his persuasion, he threatened them with a coroner's inquest if *they gave the patient anything* without express permission. Above all things he was to have no milk. That curdled and loaded the bowels with solids. Then the foot of the bed was to be elevated to lessen the pressure in the abdomen; a morphia injection was given, and nothing but sips of water with a little arrowroot. For the first few days he visited the patient five or six times a day. Almost immediately the vomiting was reduced to about once in twenty-four hours, the patient became easy and slept, but the abdomen was tense. Twice he performed paracentesis (for the relief of pressure), being careful not to allow the trocar to remain in the intestine longer than a few minutes, for fear of a fistula. On the twenty-fourth day at intervals a very little flatus was passed, on the twenty-sixth large quantities and later in the day, a few small scybalæ. Again, during the night a copious pultaceous motion, and this again followed by three days by prodigious quantities of thin fæcal fluid.

From the method in which that case was treated we see that 'Rest' was to be applied with the meticulous care and rigidity of a Calvinistic doctrine. Rest was to be secured first, by sedatives—to place the bowel at ease and relieve pain; the bowel was to be restrained from all manner of work by absolute starvation; he declared he had never seen starvation cause death in a case of intestinal obstruction, however prolonged. The bowel was not to be disturbed by any act whatsoever, such as the giving of enemata or 'rectum tickling', as he most unprofessionally phrased the practice. 'Nature', he said, 'is late in working a relief and patience is needed.' His critics said his treatment of intestinal obstruction was not new and modern surgeons will declare it to be bad. His medical critics, however, were wrong; opium and starvation had been often prescribed and employed in such cases; rest had been enjoined, but Thomas was the first to apply rigidly and completely the principle of rest as a logical system to such conditions, and to carry it out in the form of 'enforced, uninterrupted and prolonged rest'. In cases of fracture of the femur, in order that the patient might escape the disturbance caused by the act of defæcation, he placed the bowel at rest by sedatives and low diet,

[1] *Intestinal Obstruction Thirty Years Ago.* Presidential address, Liverpool Medical Institution, October 1913.

but never succeeded in keeping it still beyond the twenty-first day. There is all the difference in the world between the pious enunciation of a principle and its strict, systematic, and complete application. Therein lies the difference between Thomas and his predecessors.

It has been said that Thomas's methods of treatment are not founded on a knowledge of anatomy, physiology, and pathology—the only rational basis for a means of treatment. That, in one sense, is true. 'Surgery is an experimental science,' he states. All his life long he kept making experiments in his methods of treatment, closely observing and carefully recording the results night by night. The conclusion he drew from these years of toil was that the more strictly he observed the principle of rest in his method of treatment, the better were his results. But it would be a complete misrepresentation of the case were it to be said that his methods were not based on a knowledge of the anatomy and physiology of the human body. 'Men admired my splints as if I were a blacksmith,' he wrote, 'but the principles on which they were framed they never could see.' We shall examine those principles in connexion with the hip-joint. We shall find he is to reintroduce to us a very old kind of anatomy, physiology, and pathology. Thomas never thought in terms of muscles, but of parts; when in ordinary-day life we execute movements, however perfect our knowledge of anatomy may be, we do not think of the muscles which produce them, but only of the segments or parts of the limb or body we wish to move. The anatomist or physiologist who would sing, play golf, or acquire any skilled series of movements is well aware that his professional knowledge gives him no advantage; the teacher who corrects his faults knows nothing of muscles—only of right and wrong movements. Yet that teacher is a real anatomist and physiologist, and it is in that sense that Hugh Owen Thomas was an anatomist and physiologist of a very rare kind. When he came to apply his doctrine of rest to the hip-joint he saw that it could not be done by applying the long splint to the side of the body and lower limb—even if it stretched from the arm-pit to the external malleolus. Such a splint lay outside the axis of the hip-joint; it was separated from that axis by the lever represented by the head, neck, and great trochanter of the femur. It could not be fixed to the side of the chest because there the splint crossed the ribs at their point of greatest movement. To cross the axis of the hip-joint, so as to secure a complete control of its movements, the splint must be applied from behind and carried up the back where the ribs are at rest, for the dorsal segments of the ribs undergo only a rotatory movement where they are covered by the spinal musculature. He therefore applied his hip-splint to the dorsal surface of the body and thigh. He realized that no two people are shaped alike, and that the splint must be accurately moulded for each patient, and only one with

a knowledge of anatomy could apply it. He therefore chose a pliable material—wrought iron—of sufficient strength, and invented the tools by which it could be shaped, and adjusted the splint to the patient's body with his own hands. He considered that the fitting of a splint was the surgeon's duty.

He observed that in all movements of the lower part of the body—in walking, turning, or bending—two joints were correlated in their action, the hip and lumbo-sacral joints of the spine. He saw that a limitation in the movement of the hip could be compensated for by an increased action in the lower part of the spine, and on that observation he founded his test for demonstrating and estimating the degree of limitation in the movements of the hip-joint. He realized that the hip-joint could not be fixed, could not be given rest, unless the dorso-lumbar region of the spine were also fixed. Movements of the knee also affected the hip; the knee had also to be fixed to give the hip rest. To fix these joints he invented his hip-splint, and fashioned it in such a way that it could be fitted and attached to sound parts of the body and could be so placed that it would assist the weaker groups of hip-joint muscles against their stronger antagonists. He therefore placed the main supporting bar of his hip-splint along the back and prolonged it to fit the flexor aspect of the thigh and leg, bent so as to support these parts and relieve the flexor muscles of the hip from those burdens which disease had thrust upon them. He did not know why, but he did know that these muscles would begin to relax so soon as they found they were relieved of their involuntary burden. But he did much more: he saw that the splint must be perfect in its fit, and its effectiveness; he saw to that day after day and week after week, moulding the splint as the muscles relaxed, thus leading the parts in ease down the ladder which they had slowly climbed in pain. We see that he carried out, just as he proposed it should be carried out in the treatment of intestinal obstruction and as it never had been carried out before, in cases of diseased hip-joint, a system of 'enforced, uninterrupted and prolonged rest'. 'A man', he said, 'who understands my principles, will do better with a bandage and broomstick than another can do with an instrument maker's arsenal.'

His discoveries and skill as an applied physiologist we can illustrate also in connexion with the hip-joint. A hip-joint which possessed the normal range or radius of voluntary movement was in full health; its articular surfaces, ligaments, bone, muscles, and nerves could not then be the site of injury or of disease. If the movements were limited then some part of the machinery of that joint was affected by injury or disease; the degree of the limitation was a sure index of the extent of the mischief. If it was found that on comparing the limits from one week to another there was a greater degree of restriction, then that joint was undergoing

an increasing degree of pathological change ; if, on the other hand, the voluntary movements were less restricted, then that was a sure index that resolution was at work. He invented accurate tests for estimating the extent of movement at the hip-joint by placing his patient in a supine position on a flat surface so that he could observe and eliminate the lumbo-sacral movements before estimating the mobility of the hip-joints. Pain, heat, swelling, and redness had their value as diagnostic guides, but for him the most delicate and practical test for disease or derangement was that of use. Over and over again he was able, by the application of these physiological tests to recognize incipient stages and latent residues which escaped the eye trained in orthodox methods. He was indifferent as to how far that limitation was due to reflex effects or how far they depended on voluntary protective efforts on the part of the patient ; in either case the muscles had to be put to rest and for that there was but one means—the hip-splint he had elaborated on a definite anatomical and physiological basis. One of his physiological tests he rightly regarded as of the greatest value—the one he applied when he removed a splint from an injured joint or limb. If the patient after removal of the splint had a power of movement and could by an effort of will poise the limb exactly in the position in which it had been fixed in the splint, that was evidence of complete muscular control and of sound health in the part.

In 1883, knowing nothing of Wolff's law, he enunciates the doctrine that 'Time and Physiological Action will commode the part to the direction of the employed force' (*Contributions*, Part II, p. 121). From beginning to end we see that his orthopædic practice is founded on the truth of that law. Of greater importance, from a practical point of view, is his doctrine of 'unsoundness'. Much of his practice is founded on this doctrine. An unsound part was one which was the site of disease or injury ; it was one in which inflammatory processes were taking place. For the orthopædic surgeon a state of 'unsoundness' was of the greatest import because such a part was then plastic and could be moulded. The deformed knee was most easily straightened when it was in an inflammatory state, and the badly set fracture when it was in a stage of healing. We see him apply this doctrine to the rectification of deformities of all kinds. The deformed part—be it knock-knee, an ununited or a mal-united fracture, or a deformed but 'sound' joint—have first to be reduced to a state of 'unsoundness'. He had many methods of setting up a physiological state of unsoundness in a part—by percussing it, wrenching it, or applying the process which he called 'damming'.[1]

[1] Thomas introduced the practice of damming for the treatment of cases of delayed ununited fractures in 1876. In 1903 Bier introduced this method which Thomas had constantly taught and used as a means of treatment from 1876 until 1891—but British and American surgeons speak of it as Bier's method !

His application of such means for the treatment of deformities was the corollary of his law of ' Rest '. Rest placed tissues in the most suitable circumstances for reparative processes becoming effective, so that the part became sound and fit for use. If the opposite condition was desired, then unrest—irritation—would render the part unsound and plastic; the diseased tissues would be forced to make unnatural efforts to effect repair. Movement in a joint caused an exuberant effort that ended in ankylosis; movement or irritation at the site of fracture resulted in an exuberant callus. If, then, he wished to reduce a deformity, he excited unsoundness in the area in which the deformity existed. For a like reason, if he wished to excite a sluggish tissue to action, as in an ununited fracture or one in which union was delayed, he irritated the tissues by various physiological methods—chief of which was percussion at repeated intervals by a masked hammer or the application of constriction above and below the site of the fracture or lesion (' damming '). He believed by thus hampering the circulation of a part he irritated it, set up in it a condition of tissue unrest and evoked increased efforts towards repair. He applied the same form of treatment to recurrent dislocations of the shoulder-joint, and believed that a similar treatment was suitable at the knee-joint if there was a tendency for the internal cartilages to become dislocated.

When he came to design his knee-splint he utilized his intimate knowledge of the living human body. He was ' guided by his memory of the natural outline of the part '. Nature has two methods of providing limbs with the degree of rigidity necessary for movement: in vertebrate animals she utilizes an internal or central support; in crustaceæ and insects a peripheral or ensheathing support answers her purpose. We have no reason to suppose that Thomas borrowed any suggestion from the crab or lobster, yet his knee-splint is based on the ensheathing principle exemplified by their limbs. He simplified the sheath design by cutting away all unnecessary parts, leaving only a basal or inguinal ring, with inner and outer bars to represent the complete sheath. He saw that he had to utilize the natural base of the limb—the prominent and fixed parts of the hip bone—as a base for the new skeleton with which he was to supply support to the damaged limb. He therefore left intact the basal ring of the sheath and, by an exact study of the living parts, moulded the inguinal hoop to the supporting points of the pelvis—the ischial tuberosity and projecting iliac parts of the pelvic basin. He gave his sheath rigidity at its distal or pedal end by uniting the lateral supports. He fixed the foot in the distal end so as to keep the limb fully extended and incapable of movement. He left the circulation of the limb free and what pressure was necessary for fixation or for reduction of deformity was applied to healthy parts. He thus furnished the lower limb with a new and

temporary skeleton which relieved all its bones of work and stress, and gave the muscular engines complete rest.

It is when we watch Thomas undertaking the treatment of deformities of the foot that he is a true, if unconscious, disciple of Hunter. He bases his treatment on a knowledge of function and with the sure touch of genius hits at once on the simplest and most effective means of putting his principle into practice. A woman, Mrs. E., brings her son in an early stage of flat foot for treatment. He informs the mother

'first, that "steels" are not required [she had thought otherwise]; secondly, that the remedy for the existing condition is *to assist the boy to continue the inturn of his feet*; thirdly, that hitherto the boy was making, by his will, directed to his calf muscles, an effort to avoid deformity; fourthly, that these muscles subjected to too continuous an effort would become tired, then probably the foot might rapidly splay, other muscles then coming into play, but only to aggravate the difficulty—that the remedy is simply to specially form the boot heels and that *leather will do the labour* which, at present, is continually thrown on certain muscles, which are not only doing their own work, but are sustaining a weight which ligaments[1] for a time are unable to sustain.' The mother, however, remained unconvinced. 'What!' said she, 'only to put a bit of leather on his shoes and still make him walk with his toes turned in?' Thomas made another attempt 'to explain why merely wearing a moderately high heel well sloped, so that the outer depth of the heel of the boot should be three-quarters of an inch and the inner edge one inch, was all sufficient for a pair of feet in the initial stage of splay.'

Thomas learned 'the crooked-heel' method of treatment from watching the development of flat foot when patients, who had sustained Pott's fracture, commenced to walk. He assisted the overstrained muscles of the instep by 'crooking' the heel of the boot, so that the weight of the body was thrown towards the outer side of the foot. But the woman, like Naaman of old, 'was wroth and went away.' In an equally simple and effective manner he gave rest to the metatarso-phalangeal joints of the foot, particularly in cases of hallux valgus, by the simple means of throwing a raised bar across the sole of the boot. By this simple method the strain in walking falls upon the necks of the metatarsal bones instead of upon the toes and their basal joints.

The instances just cited to illustrate Thomas's 'principles and practice' have been chosen from the lower limb. As regards the upper limb, we see him again bringing his practical knowledge of anatomy to bear on the shoulder-joint. As at the hip, he realized that in all shoulder movements two joints were involved: the scapulo-thoracic and the scapulo-humeral. It was his recognition of this fact which led him to plan a new means

[1] In the normal foot muscles alone maintain and balance the arch. It is not until the muscles give way that a load is thrown on the ligament. Ligaments are incapable of sustaining a steady weight without undergoing elongation.—A. K.

for the treatment of dislocations of the scapulo-humeral or shoulder-joint. That joint could not be manipulated with precision until the scapula was fixed. He again utilized a basal ring—built into the side of his dislocation chair—against which the scapula could be fixed when the arm was drawn through the ring for the purpose of reducing a dislocation of the shoulder-joint. Further, we see he has grasped, in a way no one had done before him, the essential differences between lower and upper limbs. The lower limbs are framed and constituted to serve in the support and locomotion of the body ; their muscles are fixed and tuned to serve these functions. Hence when he sought to rest their muscles, he fixed the limb in long rigid splints—for preference his knee-splint. But in the upper limbs the anatomical and functional conditions are totally different ; the arms are framed not for support but for free movement ; they have no rigid basal girdle to which a fixation apparatus can be applied. As usual he fell back on the simplest means—his ' gauge-halter '—which in the upper limb takes the place of the knee-splint in the lower limb. His gauge-halter is simply a neckerchief, tied round the neck so that its loose ends fall down the breast. The loose ends are tied so as to form a sling for the support of the flexed arm, but tied to the wrist and sealed so that neither the patient nor his friends can take liberties with the surgeon's treatment :

' This gauge-halter,' he writes, ' when employed by me is never varied or undone until the patient is cured. Rest has to be enforced, uninterrupted, and prolonged. It is a very simple surgical appliance, but one which I frequently employ to the exclusion of all other mechanical aids. For fractures of the condyloid portion of the humerus it is, after due consideration and observation, my firm conviction that slinging the arm by a gauge-halter only, is the acme of treatment. I am very wary that none but myself meddle with it, and examine periodically the arrangement of the cord part, especially if the case is not doing well. A wily female deceived me on one occasion by cutting the gauge behind the patient's neck and stitching it up again. After my detection of her I always examined the cord behind the neck and have since caught several offenders.'

We thus see that although he completely alters the means he adopts in the treatment of injuries and diseases of the upper limb, the principle remains the same. He gives the part rest and secures a free circulation of the limb. His change in means was determined by the essential differences in structure and function which exist between the upper and lower limbs—differences which many of his followers have failed to realize.

To form a just appreciation of the writings of this Liverpool surgeon, it is necessary to know something of the various movements which swept across the practice of surgery during the period covered by his professional

career. When he became an apprentice to his uncle in St. Asaph in 1851, the use of anæsthetics was becoming established, but the more his experience became extended the less did he rely on the inventions of Morton or of Simpson. He had been practising for seven years in Hardy Street when Lister, in 1866, announced his discovery of wound-infection, a discovery which ultimately revolutionized operative surgery. That discovery scarcely affected Thomas's practice.

For some years previous to the introduction of the antiseptic method, I practised the open method and was well satisfied with the results obtained, but on the publication by Professor Lister of his successes, I at once commenced the practice of antiseptic surgery and continued to practise it for three years with the result of being perfectly satisfied that its merits have not been over-stated nor the trouble necessary for carrying out the details, exaggerated. I returned, however, at the end of that time to the open method and have since laboured to improve it, so much so, that I am emboldened to assert that the open method, in results and successes, are equal if not superior, to anything to which antiseptic treatment has yet attained.

In cases of compound fractures, he laid open all the recesses of the wound and washed them out with water, or salt and water. Thus, of the Listerian movement and all that the antiseptic method entailed, Thomas was little more than a spectator.

Another movement which was initiated in New York by H. G. Davis, C. F. Taylor, and Louis Sayre during the early 'sixties brought out certain critical and pugnacious qualities of which Nature had given him a liberal endowment. He was convinced he had grasped the great principle of rest more completely than they, and had evolved much more effective means of applying that principle in the treatment of injuries and diseases of bones and joints. Yet he saw his British colleagues extol their methods and appliances and pass his efforts by with neglect. The New York school were advocates of extension as a means for fixing and resting disordered limbs. Thomas said the practice had been tried in England for thirty years and was abandoned because it was wrong in principle and the results obtained in practice by its use were bad. His language and epithets were certainly not calculated to further the objects he had in view. 'Several of my friends', he wrote, 'have expressed their objection to the habit I have indulged in, of criticising the treatment of others. My answer is that the errors of past practice must be laid bare, otherwise the reformed treatment is apt to be leavened with the errors of the old.'[1]

Another movement which occupied the close attention of surgeons in Thomas's time was the excision of joints. He knew very well that

[1] *Contributions*, Part III, p. 104.

fifty years before he was born, this conservative form of surgery was conceived and put into practice by Henry Park in the Liverpool Infirmary. As a student in Edinburgh he heard Syme extol its benefits ; when he was in full practice as a surgeon, James Spence was proclaiming that its thorough application would open up a new world in surgery. In Thomas's opinion, the world which excision opened up was one of unnecessarily maimed limbs—limbs which could have been saved, or at least cured equally well, had the surgeon been content to play the patient part of Nature's assistant. How he came by that opinion, the following extracts will show :

But as I dwell in a large town, endowed with several large hospitals, in charge of enterprising surgeons, who inspired by the spirit of the profession of our times, prefer to cut mechanically what could be unloosed physiologically, I have thus been enabled to notice what can be gained by excision of diseased articulations.[1]

Excision was very successful, so far as not being attended with a high mortality, and the limb after excision was as superior to an artificial limb, as a limb cured in useful form, though with a defective joint, is superior to a limb in which a joint has been excised.[2]

In brief he believed, as a result of prolonged observation, that there was no place for the operation of excision of joints in surgery ; the limbs which could be saved by excision could also be saved, but in a much more useful state, by the application of rest, uninterrupted, enforced, and prolonged. If rest could not save them there was no alternative short of amputation. In estimating the merits or demerits of excision he pointed out more emphatically than any one had done before that there was a natural history of joints. The elbow-joint had a recuperative power beyond all other joints of the body, yet even in that joint, good as the results of excision might often prove to be, he held that the cures obtained by 'natural means' were superior in every case.

It was during Thomas's time that manipulative surgery or 'bone-setting' had one of its periodical phases of elation. In 1867 Sir James Paget, impressed by the writings of Dr. Wharton Hood and by his own observations, commended with the weight of his great authority the methods employed by bone-setters as the most effective means of treating limbs and joints which had become stiff from injury or from disease. Now there was no one in England so well qualified to express a reasoned judgement on the efficacy of methods practised by bone-setters as Hugh Owen Thomas. In this matter it is best to let him speak for himself :

For many years after the commencement of my experience in surgery, I had the opportunity of observing the practice of those who had acquired a good reputation for skill as successful manipulators. Their forcible

[1] *Contributions*, Part VI, p. 95, 1886. [2] *Contributions*, Part II, p. 147, 1883.

operations and passive motions were supposed either to lead to, or hasten on, the recovery of joints injured or otherwise unsound. I have resorted to these performances and for many years believed that my interference assisted recovery. Long ago I have, from a more complete knowledge, confirmed by crucial tests, so selected them that I cannot find suitable cases upon which I would perform the deception known as passive motion. And, whereas, in the earlier days of my experience I believed that much aid was given to recovery by passive motion, now I know, by well attested facts, that some of my marvels of my past practice had been marred by the very treatment I was so proud of.[1]

That was the conclusion he reached after a lifetime of close observation, not only of cases which had been under his own care and under that of his father, but also cases treated by bone-setters of great repute.

His abandonment of ' manipulative surgery ', and of passive movements for the recovery of disabled joints, was not altogether a result of his experience ; his experience was supported by every observation he could make on the state of diseased or injured tissues. He could not see how it was possible for movement to do otherwise than increase the irritation of the part, to aggravate the inflammatory process, and to increase the amount of exudate thrown out—the very substance out of which adhesions are formed. He knew from direct observation that such was the case. Nor could he conceive how the disease or injury could be lessened by passive movements, massage, or friction ; no one has ever shown how they could be. But there is proof that rest favours the reactive and reparative powers of tissues and lessens the formation of adhesive matter. The principles which guided him in practice chimed with his experience ; surgeons were misled in favour of manipulation by three circumstances : (1) a lack of observation on a sufficient number of control or passively treated cases ; (2) a lack of patience ; (3) the lack of a test to tell them when the joint was sound. He knew that once the part was sound the muscles would again come into action ; they could not act normally until the diseased condition had been replaced by health. When once that point was reached he had no fear of adhesions ; normal volitional movements would overcome them more surely than the most skilled manipulations. The following quotation illustrates the forcible way in which he expressed himself in this matter : ' It would indeed be as reasonable to attempt to cure a fever-patient by kicking him out of bed, as to benefit joint disease by a wriggling at the articulation.'

Like John Hunter, his opinions and practice altered as his experience and knowledge increased. ' My present opinion ', he wrote, ' concerning late incisions for pus within the elbow-joint is contrary to the one which I held fifteen years ago ; but my change of view was gradual and unavoidable, being the effect of clinical observation.' We have seen that he tried

[1] *Contributions*, Part VI, p. 66.

manipulative surgery and abandoned it; he did the same as regards the Listerian method of treating wounds; he abandoned aspiration of fluid or blood from joint cavities after years of trial. Perhaps the best example of his change of practice relates to his treatment of fractures of the neck of the femur, of the patella, and of the olecranon. From being the lesions he was most afraid of they became the ones which troubled him least. It is not necessary here to describe the appliances he used; his aim was to secure (1) perfect fixation of the part to ensure absence of friction; (2) freedom of blood supply; (3) an attitude of indifference as regards obtaining perfect symmetry. We see the critical and sceptical temperament with which he was endowed from the following extract:

> Indeed my experience incensed me with doubts, whether surgical treatment (in fracture of the patella) was hitherto any aid to repair, and with a belief that it was only of some help in bringing about restoration of symmetry. Observing the results of the practice of others and my own, I was forced to the conclusion that perfect restoration of symmetry was of no value towards gaining a rapid cure and a useful result. . . . It was thus becoming evident to me that the acme of treatment would be the adoption of some means that would be purely supplemental to the natural or spontaneous mode of recovery, so that the inherent tendency to repair would not be hindered. (1879.)[1]

Hence in fracture of the neck of the femur he applied his hip-splint, with rest in bed; in fracture of the patella, his knee-splint in the form of a walking calliper; and in simple fracture of the olecranon he slung the arm at an obtuse angle in his ' gauge-halter '. But as regards treatment of muscles his practice never changed. He speaks of them as John Hunter did, as acting as if possessed of a species of intelligence. The ' intelligent muscles, finding their labours no longer needed [after application of his hip-splint] take a rest until invited to enter again on duty '. . . ' If a muscle manifests a flicker of movement under volition, it will recover its full power,' is another instance of physiological observation. He treated muscles as he treated his patients. He relieved the weak and oppressed, and restrained the strong. If the flexors of the elbow were paralysed, he saved them from their over-strong antagonists, by keeping the elbow partially flexed; he dorsi-flexed the wrist-joint by a special splint to nurse the paralysed muscles of the forearm.

In truth Owen Thomas was the lineal descendant of John Hunter, and had the misfortune to appear in a period when the Hunterian traditions were overshadowed by brilliant and great advances made in many departments of medical knowledge. The microscope seemed to reveal a world of disease for which Hunterian methods were out of date, whereas it was the same world of disease looked at a little more closely. It was

[1] *Contributions*, Part VI, p. 57.

a period in which the surgeon boldly essayed to play an active, not a passive, part in healing, and in such a company there was no place for Thomas. It is true that he had not studied living matter as Hunter had, but that very inventive genius which permitted Hunter to plumb some of Nature's deepest secrets was also given to Thomas, who spent it in the design of appliances to secure the principle closest to his heart, physiological rest. If Thomas had spent that gift on commercial projects he would have been one of the most prolific and successful inventors of his time. Yet were I to emphasize the greatest legacy he has left to Medicine, it would not be his splints or appliances, his principles, his practical applications of anatomy or of physiology I would underline, but his personal care in the service of his patients. No trouble was too great for him if his attention was needed to effect a cure. I will cite only one example—one which illustrates not only his peculiar ability as a biological surgeon, but his remarkable gift of taking pains :

A young girl consulted me who was much annoyed by the slipping of her patellæ over the outer condyles whenever the knees were bent. It appeared to me that, if I could enlarge the upper surface of the outer condyles, then the knee-caps could not ride over them. After the right and left outer condyles had been moderately percussed *every week during five months* the left patella ceased to ride over the outer condyle and after nine months' percussion, the right patella also ceased. (Pt. VII, p. 53.)

If genius is a 'capacity for taking pains', then Thomas was a genius ; no one who will take the trouble to ascertain what he did and the circumstances under which he accomplished his life's work will fail to see that he has earned himself a place among great British surgeons.

THE PREVENTION OF DEFORMITIES

BY

Col. H. M. W. GRAY, C.B., C.M.G.

THE PREVENTION OF DEFORMITIES

ALTHOUGH in civil practice a medical man can carry out his work in a very independent manner, as a military officer during a campaign he must regard himself, in a way, as part of a great machine whose objects are to prevent and treat disease and to render wounded men fit again in the shortest possible time. The component parts of this machine must be properly assembled and regulated if the best results are to be obtained. The driving force is the desire to give the best which medical and surgical science can provide. It is very apparent that on the smooth working of this great machine depend the prevention of deformity and restoration of efficiency in a huge number of the picked men of our empire.

Value of Co-operation. Justice cannot be done to wounded men unless the fullest possible co-operation exists amongst their attendants, from the time when the patients first come under medical supervision until convalescence is complete. This is especially the case during a war carried out in a foreign country. It is evident that collaboration everywhere, between medical officers of all departments, both professional and administrative, is imperative. Antagonism, as opposed to criticism, should have no place amongst those united in common cause for the good of the soldier. Liaison, interchange of information and opinion, must be fully cultivated. Workers farther back can constantly give suggestions for improvement or alteration in treatment carried out by those nearer the front. On the other hand, it must not be forgotten that the treatment in advanced units, even in regimental aid posts, has profound influence not only on the immediate danger to life and limb but also on the ultimate result. It is here that prevention of deformities must be begun, and thereafter continuity of treatment on definite lines must be established.

At the outset the ideal of rapid, smooth, warm, comfortable transport must be striven after so that the least possible strain may be put on patients already severely exhausted. Special provision in every way must be made to prevent or remove surgical shock. Structural arrangements and internal organization in all hospital units must be planned so that rapid disposal and immediate operative treatment of patients may thwart the evil effects of persistent loss of blood or virulent sepsis. Thus it will be appreciated that administration must always be subservient to professional exigencies. When administration fails, there may result

a loss literally of hundreds of lives or limbs—to say nothing of the loss of function to hundreds more.

Last but not least, the psychology of the worker must be considered. Sympathetic appreciation of the difficulties in treating the wounded man at his various halting-places should be fostered by M.O.s of other units. There are few who have had experience of periods of stress at all the different stages but can describe the various ways in which this stress tells on the professional mind. The sympathy and encouragement of those farther back from the line should be especially strong for those in more advanced and more dangerous areas, whose work is conducted under very difficult conditions but who strive to attain often impossible ideals. Words cannot describe the stress and anxiety in the front areas during a big battle. At any time during its progress the number of casualties may compel a complete change in plans. When fighting has been very severe, even the distressing knowledge that delay in operation means a corresponding addition to the death-roll cannot be allowed to interfere with evacuation down the line of all who can possibly travel. But in such circumstances the surgeons at the front cannot be blamed for the less favourable condition in which their patients are sent on. There has been no time for anything but essentials in dressing. All the same the work of a unit should always be judged more by the physical condition of the patients who have been sent from it, than by the numbers passed through its books—the smaller the number, the better should be the condition.

In the present war one of the striking results of collaboration between the surgeon and the bacteriologist has been the improvement in the prevention and treatment of sepsis. For example, the ravages of gas gangrene and the rapidity of its development used to be a despair-begetting nightmare to surgeons trained under pre-war conditions, but now that its pathology is understood it is much less feared and much more successfully combated.

Extensive application of the principle of excision of wounded parts, especially when carried out in the pre-inflammatory stage, has revolutionized the treatment of wounds and has rendered possible the prevention of deformities. More than any other measure has it preserved movement and function. Surgeons at the front may be blamed by surgeons at home for being too radical in their methods, but it must be remembered that the missile or the accompanying sepsis is usually responsible for the damage which maims the patient. The experienced surgeon, in his operation at the front, merely follows definite indications which have been established and which have regard to the utmost conservation compatible with safety to life. Even the best surgeons fresh from home have to serve a long apprenticeship before they attain the efficiency in saving life and

limb which some of their young pupils have achieved in work at the front.

The whole trend of collaboration is towards successful conservatism. The chief function of the military surgeon is thereby developed to the full, that is, to render the greatest number of wounded fit for the fighting line in the shortest possible time, or to return the discharged man to civil life with as little disablement as possible.

While primary excision of wounds followed by primary or 'delayed primary' suture is, when possible, the best conservatism, yet there are many wounds which for various reasons cannot be sutured. The condition of the patient, the amount of tissue destruction, and the nature of the infection may, each or all, make delay imperative. The modern method of treating open wounds, by maintaining or procuring sufficient sterilization, soon renders possible further surgical procedures to promote rapid and complete healing. Here again the beneficial results of collaboration between surgeon and bacteriologist are evident. All along the line, the object must be to get wounds to heal with as little loss of tissue and with as little scarring as possible, so that deformity and limitation of movement may be reduced to a minimum. At all stages, however, the danger of sepsis, whether acute or chronic, must be appreciated. Responsibility for life entails too frequently, especially at the front, the ruthless sacrifice of part or the whole of a limb. Conservatism must not be allowed to overshadow prudence.

Value of Efficient Work in Advanced Units. It is difficult for medical officers, who work in advanced units during such a war as the present, to appreciate the enormous importance of *their* treatment in the prevention of deformity or, what amounts to the same thing in most instances, the preservation of movement. They may say that this is the function of surgeons in Base hospitals, whether abroad or at home. On further consideration, however, they will realize that efficient early treatment, even during the few hours immediately after the patient has been wounded, is of inestimable prophylactic value. The treatment which a man receives at this time is reflected in the whole course of his subsequent illness, and on it depends largely the measure of recovery which he will attain.

The three factors whose evil influence has to be combated at once in practically every severely wounded man are shock, hæmorrhage, and sepsis. These act, the one upon the other, in a very marked way. Shock and hæmorrhage have a real bearing on our subject in that they directly predispose to the rapid development of infection, especially of gas gangrene. The presence of gas gangrene demands that the affected part should be ruthlessly removed, either by efficient excision of part or whole of the affected muscle or group of muscles, or by amputation. The greater the extent of the gas gangrene, the greater the subsequent disability. At

this stage no one can accurately estimate the ultimate extent of gas gangrene, hence the necessity for rapid transfer to an operating centre.

The workers in dressing stations at the front should realize that the development of gas gangrene will practically never occur unless the free circulation of healthy blood through the wounded parts is interfered with. The more this is hindered, the more rapid will be the spread of the gangrene in the lacerated and adjacent tissues, and consequently the more extensive will have to be the operation, and the greater will be the likeli hood of deformity or impairment of movement. Shock and hæmorrhage, which enfeeble the general circulation, and tourniquets, tight bandages, tension from pent-up effusion, and lodgement of a foreign body, which more or less stop the local circulation, all predispose to rapid spread of gangrene. The blood pressure must be restored by appropriate remedies for shock-hæmorrhage. The prolonged application of a tourniquet must be avoided. It is well known that a limb to which a tourniquet has been applied for even a comparatively short period has usually to be amputated on account of gas infection. If a tourniquet *must* be applied for a long time, it should be placed close above the wound so that as much of the limb may be preserved as possible. Bandages must be applied to allow for swelling, which is so liable to occur before the patient can reach the clearing station. Bleeding, however, may be of such a nature that local compression is imperative. A note drawing attention to any treatment which, if prolonged, would be detrimental, should be sent along with the patient.

The manner of dressing a wound is of importance. The calamitous results of closure of wounds without previous thorough mechanical cleansing, i.e. excision of all possible infected tissues, was appreciated at a very early stage of the present war. It is only slightly less prejudicial to seal up large deep wounds by the external application of flat dressings, which approximate the wound margins and prevent free escape of infected effusions. . Even though the journey to the C.C.S. be short, it is often rough, and the evil effects of transport on such wounds are commensurate with the amount of jolting. No large wound should be occluded in this way. It is found that gauze, interposed between the deep surfaces of the wound from which all loose débris is first removed, forms the most efficient drain and tends, therefore, to curb the virulence of the sepsis. The gauze should be impregnated with a substance such as liquid paraffin, so that it can be rapidly and painlessly removed. Some such antiseptic as iodoform (1 per cent.) may be dissolved in the paraffin. This, as it gradually becomes decomposed in contact with body fluids, exerts inhibitory effect on organisms actually in the wound. Again, in wounds of the head, where disorganized brain and effused blood are being pressed out, the flatly-applied dressing tends to stop the exit of discharge

causing accumulation in the brain and in many cases, especially during a jolting journey, increasing the cerebral injury with consequent increase of paralysis. The dressings should be arranged so that free escape of effusion is permitted.

The evil effects of jarring movements in large flesh wounds must further be obviated by proper support with suitable splints. A big wound of the thigh without fracture of the femur requires treatment by a Thomas's splint outfit just as much as when a fracture exists.

Visible foreign bodies or loose displaced fragments of bone should be removed. Their further displacement during transport, especially when aggravated by pressure of dressings, may result in serious damage, for example, to the brain or a joint, or they may cause erosion of a large vessel with resultant loss or destruction of life or limb.

While at dressing stations the dictum is true that all wounds which have been laid open by the missile should be kept open until operation is possible, it cannot be advised that all wounds should be at once laid open by the surgeon's knife. There are all gradations from the simple sterile puncture ' entrance and exit ' bullet wounds with no evident injury of deeper parts, to the huge, soiled, gaping shell wound. The former type requires little treatment, that of the latter is obvious. Intermediate types require judicious and varying management, which is rendered all the more difficult because of the enforced limitation of operative interference. Bleeding must be stopped, however, to avoid the prolonged application of the tourniquet. Small superficial wounds, under which great tension exists, usually require extensive operation and therefore should not be tackled. Such cases should be sent on without delay. If the skin punctures of a bullet are accompanied by evidence of serious muscle injury, the part should be splinted, but judgement must be used to prevent the squandering of splints.

Selection of cases, owing to the excessive number, may be necessary during a ' push '. A severely wounded man may die for want of immediate attention whilst adequate treatment is being given to a lesser injury. The ideal is difficult of attainment, the work is harassing, the responsibility is overpowering, but the work of Advanced Medical Officers has usually been most praiseworthy.

The prophylactic value of proper fixation by the application of splints in injuries of joints must be remembered. Movement, especially passive movement, may introduce sepsis into a previously sterile synovial cavity or may make foreign bodies bore deeper or break new ground, with the result that the patient may have a permanently disabled joint or lose the limb. The limb may have to be fixed in an unusual position—that which causes the least amount of pain.

The preventive value of efficient splinting in bone injuries is well

exemplified in the case of fracture of the femur. All splints must be suitable for transport. They must be simple, easy to apply, and take up as little room as possible. They should, as in the case of Thomas's splint, render so-called 'self-contained extension' possible. Before the use of the Thomas's splint became general, the mortality in cases of fractured femur in the C.C.S.s alone, and during so-called 'peace' times, was nearly 50 per cent. During the opening phases of a big battle, previous to which the application of Thomas's splint had been demonstrated in all the field ambulances of one of the armies concerned, the number of cases of fractured femur admitted to the C.C.S.s of that army was 1,009. The mortality was 15·6 per cent., a reduction of over 30 per cent. In addition to this the cases, with the exception of about 5 per cent., were in such good condition that they could be subjected to operation at once. Formerly a delay of ten to fourteen hours was required to allow of recovery from the severe shock, during which period sepsis gained a terrible hold. Severity of operation was therefore correspondingly reduced. The opinion had previously been gaining ground amongst certain surgeons, indeed had been repeatedly expressed, that more lives would be saved if amputation were done in every case of fracture of the femur. Yet the number of amputations in this series was only 17·2 per cent., which alone shows that more conservative measures were possible than ever before, and it is impossible to estimate the amount of prevention of ultimate deformity.

However well *general* principles may be observed, want of attention to *details* and to their adaptation to each individual case may cause irretrievable damage. Take for example the application of extension to a fracture of a long bone. The method of application and the amount of extending force used must be modified according to the general condition of the patient, the condition of the circulation of the limb, the presence of wounds in the parts distal to the fracture, the possibility of trench foot and so on. In a badly-shocked patient that method must be used which entails least handling of the part and which can be applied most rapidly. If a large amount of muscle is shot away, the amount of extension which could be used with safety in a less lacerated limb may cause gangrene from stretching and occlusion of the vessels, or paralysis from stretching of the nerves. Too great a pull on a clove-hitch or other knot around the ankle or wrist has caused sloughing of the skin and even loss of a part or the whole of the foot or hand in far too great a number of cases. This is especially liable to happen after lesion of the cord or main nerves.

Arrangements should be made whereby a constant supply of suitable splints, especially of Thomas's knee or arm (hinged) splints, will be assured, in the firing line or as near it as possible.

Drivers of ambulance wagons or ambulance cars play their part in

the general scheme of collaboration. However strong the rest of the chain of treatment, a thoughtless driver may prove the weak link which makes that strength of no avail. The evil effect of rough transport in producing shock and favouring the rapid development of sepsis is well known. A considerate driver, on the other hand, who carefully picks his way and regulates his pace according to roughness of the road and the condition of the wounded in his car, contributes in large measure to the saving of life and limb, and adds an important aid to the prevention of deformity.

WORK AT CASUALTY CLEARING STATIONS

In the following remarks it will be seen from all points of view that the quality and organization of work at this stage have a very special influence on the subject under discussion.

Experience has shown that the further a seriously wounded man is transported before he receives adequate surgical attention, the less chance there is of saving his life or his limb, and the less chance also of preserving the function of the wounded parts. Obviously, therefore, adequate provision must be made for the performance of all necessary operations as near the firing line as the military situation will permit. It is at this most important stage of the wounded man's career that the administrative officer incurs probably his greatest responsibility as a professional man. The record of loss of life, limb, and function does not appear in the scheme of things by which his capacity is judged, nor, to put the matter on a lower plane, does the ultimate irreplaceable loss to the empire in efficient man-power receive proper appreciation when weighed against the comparatively insignificant possible loss of replaceable material. From this point of view the selection of the site of a C.C.S. is of the highest importance.

Shelter-accommodation and internal equipment of such hospitals must be planned with an eye to the most rapid transference to another site with the minimum of interference with surgical work. It is just when rapid moves are necessary that surgical demands are usually most clamant.

Fighting will always be more intense at one part of the front than at another, therefore arrangements must be made to cope with fluctuating numbers of wounded at the different C.C.S.s. The training of as many surgical teams as possible in all hospitals, both at home and abroad, provides operating units, which can be sent wherever most required. This movement of teams may have to be made within army areas when planning for trench raids, as well as from army to army, or from Base hospitals to armies when fighting on an extensive scale is imminent. The introduction of the team system brought about a great advance in the treatment of the wounded.

It is obvious that theatre accommodation in these hospitals should be of a most ample description. Slightly wounded men can be treated more quickly than the seriously wounded, and, therefore, different arrangements should be made in the theatres set apart for the treatment of the two classes. For example, the number of tables provided for each team must be greater when dealing with slighter cases. A prolonged war enforces attention to the fact that slightly wounded men may be rendered fit to return to the fighting line after a short period. The longer operation is postponed the longer will that period be, because the spread of sepsis necessitates more extensive interference. Early operation on three or four slightly wounded men may not in the aggregate occupy more time than will be spent in the attempt to save the life of a single desperately wounded man who will in any case be of no further use as a combatant.

Since immediate treatment of all wounded requiring operation is so essential, it is evident that thorough organization of all departments in those so-called Clearing Stations is of the utmost importance. The hospital must be planned so that time and labour are not expended unnecessarily, so that serious cases are not subjected to a needless amount of movement or exposure. Inefficiency in one department of the work may neutralize the highest efficiency in another. Untrained stretcher-bearers, for example, may, by their slowness, delay work enormously. Help from workers in one department to those in another whenever that is possible is also most valuable. To take an apparently trivial example, although it may not be usually possible in a busy pre-operation ward, during a lull in receiving the shaving of operation areas in suitable cases before the patient is taken to the theatre will appreciably lessen his time under an anæsthetic. A thorough understanding, again, between skiagraphers and operators saves the time of both. The arrangements and inter-communication of wards and operation theatres should be planned as well for ease and rapidity of transport of patients as for their comfort and protection. Examples might be multiplied indefinitely.

The selection of officers, nursing sisters, and N.C.O.s for the various posts of such a hospital must be made with great care. Officers in charge of dressing-rooms, whence patients are distributed to their various destinations, are probably, from a surgical point of view, the most important in the whole army. On their judgement largely depends the fate of the patient. They have to decide whether patients are suitable and fit for operation, whether they have to be kept in hospital or sent down the line, and so forth. In absence of experience in hospitals farther back, it is difficult for such officers to appreciate the particular types of wounds which will deteriorate badly during transport. A mistake in judgement may spell irretrievable disaster.

For C.C.S. work such surgeons should be selected as have quick sound

judgement, rapid technique, and full appreciation of the principles on which successful treatment of war wounds depends. Whatever be their academic qualifications or status in civil life, new arrivals must 'make good' before being entrusted with positions of responsibility. Sisters must not be appointed indiscriminately. One may excel in resuscitation work, another in post-operative treatment, and so on.

The type of work to be done at casualty clearing stations is or is not 'preventive' according to the rapidity and condition in which patients can be delivered there and put upon the operating table. Delay promotes disaster. Conservatism is impossible in cases where acute sepsis has become well established. Sacrifice of limbs or of other important parts has often to be made in order to save life in cases which, if they had been treated before inflammation had become rampant, would have suffered little later inconvenience. Again, when casualties are very numerous, the fact that the time of every skilled person is taxed severely, makes it impracticable and inadvisable to submit doubtful cases to a risk which is obviated in 'peace' times by the ample attention which can then be given to each patient, so that amputation has to be resorted to much more frequently.

Operation in the pre-inflammatory stage makes conservatism safe, but it seems contradictory to state that conservatism often demands what looks like heroic measures. In tackling these cases successfully, surgeons had to deal with problems on which the clear light of bacteriology and pathology had never previously been shed, although sound clinical observation had carried many far along the proper road. The skilled experienced surgeon can now approach his cases with a well-defined plan of action in his mind, which naturally is modified to the requirements of each case. He can rely very constantly, whenever it is anatomically possible, and consistent with life, on preventing or eradicating dangerous sepsis, and, when closure of the wound is possible, can suture the wound with assurance of obtaining primary union in the great majority of cases. Empirical, unconsidered attack, however slashing, results too frequently in only temporary abatement or postponement of sepsis. Each case should be approached in the same attitude of mind as when excision of a cancerous growth has to be undertaken. In so far as a surgeon neglects well-established rules, failure will follow. His capacity can be measured inversely by the number of secondary operations which have to be performed on his patients, by the number of primary sutures which break down, or again by the number of wounds which he has sutured and which do not survive the ordeal of transport to the Base without inflammation having been stirred up.

Owing to the detrimental effect of even smooth railway transport, special regard must be given to the manner in which cases are prepared

for their journey to the Base. If the smallest amount of sepsis has been left in the wound, acute inflammation is apt to be provoked with the result that sutured wounds have to be opened up or secondary operations to be performed even in cases which would have healed perfectly if they could have been retained in the C.C.S. When doubt exists as to the thoroughness of any operation on a patient who has to be evacuated in a short time, it is preferable to fill the wound with gauze impregnated with a harmless ‘ dépôt ’ antiseptic[1] or to stitch Carrol's tubes in it so that the whole raw surface may be soaked with fresh antiseptic from time to time. Wounds of soft parts as well as fractures in process of healing must be supported and fixed in ways similar to those advocated in more forward medical units, although, of course, in a more permanent if not more perfect manner.

From the earliest possible moment, deformities, which are apt to follow upon injuries to nerves or muscles or from the action of gravity, must be prevented by postural treatment in suitable splints or by other means. The use of a ‘ cock-up ’ splint in musculo-spiral paralysis and of a suitable foot-rest in cases of fractured femur may be cited as two common examples. Active movements in injured limbs should always be tested previous to operation, otherwise the surgeon may unjustly be debited with the paralysis which is discovered afterwards.

The effect of excessive strain by extension on the nerves and vessels of a limb whose other soft parts have been more or less destroyed has already been mentioned. The necessity for attention to this is still greater after a cleansing operation which has entailed cutting away more of their support. It is important also to fix in relaxation the remainder of a muscle of which part has been blown away by the missile or removed by the surgeon's knife.

Deformities from contracture of muscles, peri-articular cicatrices, and intra-articular adhesions must be anticipated and combated as soon as danger from sepsis has passed, in cases which, for various reasons, cannot be evacuated at the usual early period. Thus flexion and adduction at the hip after amputation through the thigh must be overcome by passive movements in the opposite directions. Active movements of joints should be encouraged at an early stage.

The transmission of clear, succinct notes on injuries and operations, and of other special information, is of great value to those in hospitals farther back. At the same time, reciprocity, by sending short accounts of the progress of special cases to the surgeons who performed the primary operations, cannot be too much encouraged. Such progress notes should

[1] The term ‘ dépôt ’ antiseptic is applied to one which exerts its influence slowly and continuously by being broken up into active constituents when in contact with body tissues or fluids, e.g. B.I.P.P. or I.P. (Iodoform-paraffin).

contain specific details. It is of little help to state merely that a patient has made a ' good recovery ' in the case of wounds in which the operator has followed some original or unusual plan of treatment.

A medical officer should inspect all patients before they leave the C.C.S. to see that they are properly clothed, properly splinted, and so forth, as well as that all administrative requirements have been fulfilled regarding them.

It is only during periods of severe fighting, when really efficient treatment at the C.C.S. may have been impossible, that medical officers on the ambulance trains or barges ought to have specially skilled work to do. Under their unfavourable surroundings, they are usually then compelled to adapt the principles of treatment which are carried out in dressing stations at the front. At all times, by careful attention *en route* they can of course prevent trouble, for example by adjusting the amount of extension when necessary in fracture cases and so on.

Work at Base hospitals in foreign countries resembles at one time that performed in casualty clearing stations and at another is governed by the same considerations as hold good in hospitals of the home country.

THE PRINCIPLES OF ORTHOPÆDIC SURGERY AS THEY APPLY TO THE MILITARY NEED

BY

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THE PRINCIPLES OF ORTHOPÆDIC SURGERY AS THEY APPLY TO THE MILITARY NEED

THE prominence that orthopædic surgery has assumed in this war is so much greater than is common in civil times that it is natural for inquiry to be made for the reason for this, and in presenting them it is necessary to present the principles underlying the work of the orthopædic surgeon which are not really different as they apply to the military needs from those practised in civil life. That the place now being occupied is proper is best shown by that which has occurred in the British army during the period of the war and to a less degree by that which has developed in the American army during this first year of its war activities.

With the British army, starting in the beginning of the war with no representative of orthopædic surgery, as such, upon the staff of the Medical Corps, it soon became evident that it was necessary to have men with this special training available to assist in the restoration to usefulness of many of the wounded soldiers. Naturally the man to whom the nation turned was Sir Robert Jones, and under his leadership the work has not only been developed so as to greatly benefit his own nation, but has set the standard which the American Government is trying to follow in the preparation and care of its own troops.

That which orthopædic surgery stands for primarily is the preservation or restoration of function in parts that may have been injured or diseased, so that not only will the disease be controlled but that there will be the least possible permanent limitation of usefulness. Medical treatment alone, or surgical treatment alone, which frequently stops with the relief of acute symptoms, many times leaves the individual with limitations of activities that could be corrected if the measures having to do with the restoration of function in the inflamed or damaged part had followed that which had been given by the physician or surgeon. Not only is such work possible and very much needed, but it is naturally desirable, and it is especially true in the army that the measures having to do with the restoration of function should begin at the earliest possible moment so that there may be the least possible loss of time to the service. As an illustration, an inflammation of a joint or about the tendons, such as is so commonly a part of many of the infectious diseases, frequently results in adhesions in or about the joint or tendons that would seriously interfere with the function of the part and for which the ordinary medical

or surgical treatment, which has to do largely with acute symptoms, makes no provision. Or an operation upon a bone or joint may be technically most perfect, but unless the performance is executed with reference to later usefulness, or unless the measures having to do with the restoration of function are instituted as soon as possible after the healing of the wound is completed, a result that might have been perfect may, from the point of view of function, be very poor.

The methods of treatment having to do with the ultimate usefulness of injured tissues, especially as they have to do with the extremities, naturally involves different training from that which is expected for the regular medical or surgical work, and is so distinct that there should be no conflict of effort in the use of the methods. Naturally the treatment of acute medical conditions is carried out by internists, but it is equally natural that the restoration of the function, in parts that have been damaged, should be accomplished more rapidly and more perfectly by men who have been trained to think in terms of human mechanics and are familiar with all of the possible combinations of the elements that can bring about the greatest possible usefulness. Also, naturally, much of the acute surgery upon injured bones or joints may be and many times can best be performed by the general surgeon, but it is also natural that, as soon as the primary wound healing is established, the restoration of function in the affected part will be accomplished more quickly and perfectly by those who have been trained to deal with such problems and familiar with that which can be expected in a given case, one, or two, or six months later. It is natural that the closest possible co-operation should exist between the orthopædic surgeon, the internist, and the general surgeon, so that the skill of each will be available, as it may be required, to save or restore the man who has been diseased or wounded.

In the development of the work of the orthopædic surgeon not only have the above-mentioned activities been made evident, but it has been clearly shown that the recognition and treatment of the imperfect use of the body, or parts of it, with the natural resulting strain or weakness under the stress of military activities, is not only desirable but has become a part of the activities of the department of orthopædic surgery. This part of the work, which has to do with the preparation of the man for his duties and with preventing him from becoming sick or non-effective, by developing him to the greatest degree of physical fitness, is naturally distinct from that which comes after injury or disease, but is of greater importance from the numerical point of view. In this part of the work, however, the same fundamental underlying principles should be followed as apply to that which comes after injury or disease. These involve a thorough knowledge of the mechanics of the human body, of the anatomy of the structures that have to do with motion and general function, as

well as of the physiological principles that have to do with their action or their restoration to usefulness. Such knowledge must be the basis of the work of the orthopædic surgeon, and it is essential whether the special need is the correction of weaknesses that would cause trouble later, or the correction of trouble that has already occurred.

From this it is evident that the activities of the orthopædic surgeon divide themselves into two parts, one having to do with the preparation of the men for the expected combat, and the other assisting in their recovery if wounded. The first endeavours to see that they are so trained that there will be the greatest possible vigour for the combat, and that physical defects which might have rendered them ineffective are corrected. The second has to do with the treatment of the men if injured, so that there will be the least possible ultimate crippling or interference with function. The first has to do with saving men for service who would otherwise be discharged as physically unfit and also, as the result of careful training, increasing the number of days that should be expected of them for active duty. The second has to do with the saving for service, men who but for such work might not have lived, or had they lived, might have been so crippled as to be of no use to the army.

That both phases of this work are needed there can be no question. The first is shown by the large number of men with correctable physical defects that would otherwise be exempted for service in the army, and which without such treatment not only represents a great loss in needed men power but also represents a very real potential of inefficiency or disease that will be a burden to the body politic. The second is shown by the great number of wounded that are being saved for useful service for the army or nation that, but for such work, would not only be lost for service but would represent a great and unnecessary burden upon the nation.

PRE-COMBAT

The first or pre-combat work involves:

I. Instruction in the proper use of the body in standing, walking, and other activities, so that there will be the least possible waste of energy or liability to over-strain in the performance of regular duties.

II. Special training, through setting-up drills, orthopædic exercises, &c., to overcome bad habits of carriage or body use that lead to inevitable weakness and inefficiency if continued.

III. Instruction in the care of the feet and supervision of the shoe fitting, to ensure the least possible loss of personnel through the common foot difficulties.

IV. Instruction of the stretcher-bearers and ambulance corps men in the use of the standardized splints, to ensure the least possible injury

to the man in his transport to the dressing or aid stations, or to the hospitals.

Postural Training. To understand that which is implied in I and II, it is necessary to think of the human being as a delicately adjusted machine that naturally can do its best work only when used rightly. This involves a thorough understanding of the structure of the body and of the usual variations, as well as of the physiological elements, involved in proper function. It is not difficult for any one to understand that a machine of any sort will sooner or later come to grief if used wrongly, and it should be realized that this applies to the human body as well as to the device made by the man himself. Great numbers of individuals are ' scrapped ' from the army or break down in civil life, not because they are sick, but because of symptoms which have developed from wrong use. These same individuals are oftentimes equal to greater than the average strain when properly trained, instead of breaking under strain that is well below the average.

That work of such nature is greatly needed is not to be wondered at in an army which has been recruited in a country that has directed its attention in its educational propaganda so fully to the training of the mind and has ignored so largely the principles of physical education upon which the health of both mind and body depend. In no other country has there existed so many drooped, slouched, or badly poised men and women previous to the war as in ours, and such types do not stand for physical endurance. It is obvious, however, that to give the individual a properly trained body cannot be accomplished in a day, and perhaps in this, as much as in anything else, it is shown that a great army does not ' rise up in a night '.

To make these men of army fitness is our task, and while much of this work should naturally have been performed in the schools during childhood, or while much of the work should be carried out at the camp, in the early part of the military training, there will, however, remain a great deal to be performed with the army in the field, to correct weaknesses that may have been overlooked or that have developed as the result of sickness or over-work.

In order to accomplish this work rapidly, it is necessary to have the co-operation of the man and, to secure this, practical talks should be given from time to time giving the reasons for that which is being done. With charts or tracings it is possible to demonstrate the reasons for the correct carriage, and to make it evident that there is only one right way to use the body, which is the same to-day as has been the accepted standard in all times in which attempt has been made to develop the human body to its best. It should be explained that the breathing cannot be performed best unless the chest is carried high or ' well up ', with the head erect

and chin drawn in. It should also be explained that the digestion cannot be at its best unless the diaphragm is drawn up or the abdomen drawn in or held flat. It should be shown, as each individual can demonstrate, that the diaphragm or 'guts' cannot be drawn up unless the chin is drawn in, because of the suspensory ligament of the diaphragm being attached through the pericardium to the sides of the low cervical spine. It is this that makes necessary, as well as desirable, the head erect position, and has led to the insistence that is put upon this by the athlete for running or other feats of endurance.

It should be explained that the spine has certain curves that are normal and that these are so formed that if the body is used properly there will be the greatest ease and spring in movement, with the muscles of the different parts of the body in such balance that action will result in the least waste of energy, and fatigue will come only after long or sustained effort.

It should also be explained that the bones of the feet are held together by muscles, and that only when the body is held erect are the muscles of the feet so used that strain and weakness will not result. It is easy to demonstrate that in standing erect with the chin drawn in and with the abdomen flat that the full weight is felt chiefly upon the balls of the feet and the full spring of the arch of the foot is present. It is also easy to demonstrate with each individual that if the body is relaxed, such as by simply lowering the chest or standing with the head forward, that the weight is borne upon the heels, in which position the muscles are relaxed and the spring of the arch of the foot is entirely lost. No one can stand for long in this position without weakness of the feet resulting with ultimate flat foot. On the other hand, once the feet are developed, if the body is used fully erect, flat foot will not occur and use will strengthen the supporting muscles as is expected with the muscles of other parts of the body.

Once these things are clearly explained and the desired posture obtained, the common conditions of foot weakness or back strains, which represent the two most common results of such postural defects, will disappear. Such conditions represent weakness and not disease, and weakness largely the result of wrong use of the body. Any method of treatment of these conditions that does not recognize this must be attended by only temporary success. Such conditions should be constantly emphasized as being due to weakness and not requiring medicine. Once this point of view is established, it not only makes it possible to handle large numbers of men, but it at once makes them realize that the condition is not one of sickness, requiring close supervision, but is one for which they themselves are responsible and for remedying which proper physical training is essential.

Special Training Organizations. Since with a large number of men the conditions of bad posture, with resulting weak backs or flat feet, are more marked than could be corrected in the ordinary routine of military life, special methods, by which groups of men can be handled, are necessary. To meet this need special training organizations should be established, and the men requiring development should be assigned to them for such period of time as may be necessary for overcoming the weakness. To them should be sent those having noticeably weak feet or troublesome, weak, or lame backs, general bad posture, &c. The medical part of the organization should be as inconspicuous as possible, and in so far as is possible the training given, or the exercises used, should be those employed in the training given in the regular military camps. For instance, squad or company drills ; bayonet drill, manual of arms, bomb throwing, route marching, &c., should all be used, but of course for shorter periods than would ordinarily be used in the regular training. Following each period of military activity, which should be short and made as 'snappy' as possible, should be a period devoted to some game or play in which all share and in which there is the greatest amount of relaxation from the strictness of the discipline as is compatible with the general routine. During the periods of drill, irrespective of the form, constant emphasis should be put upon the way in which the movement is made. In standing or marching, the fully erect, alert position should be insisted upon, while every special movement or exercise should be made from this position. In marching, in order to emphasize the posture, the pace should be quickened, with quick snappy action.

In such an organization the men should be divided into four groups or companies, each having a schedule carefully planned to meet the needs of the men assigned to it. The first or junior company should have a schedule made up of short periods for military activities, with frequent periods of games and also with distinct periods for rest, the idea being to stimulate the muscles but to avoid over-fatigue. The next company, to which the men from the lower company are transferred, should have a schedule of more rigorous planning, the same being true of the third and fourth companies. In the fourth company, the schedule is only slightly below that required for the full combat fitness, and it is expected here that the men will be able to march at least ten miles with full equipment without suffering strain or unnatural fatigue. Shortly after this has been reached, the men are naturally discharged back to their commands.

The admission of the men to the organization and the transfer from one company to another, with the final discharge to their organizations, should be upon the recommendation of the orthopædic surgeon in charge. Before the final discharge is made, the men must have demonstrated by the involuntary use of the body that the corrected habits of general pos-

ture, as well as the correct habits of foot posture, have become automatic. Such cases, without some such system of training, should not be retained in the army, as they would not be equal to the strain of combat training,

Fig. 2.

Fig. 3.

Fig. 4.

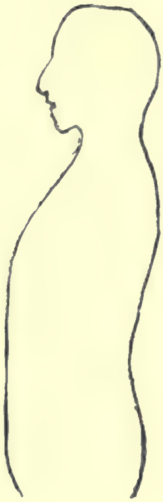

Fig. 5.

Fig. 6.

Fig. 7.

and to send such cases to the hospitals simply means less activity, greater weakness, with the result that after being sent back to the command the condition is really worse than it was before. Without such special training

discharge from the army should be recommended for these men, but with such training they can practically all be saved for the army and between 70 and 80 per cent. can be made equal to full combat duty. With the experience that this work has given it is evident that flat foot should no longer be a cause for discharge from the army or exemption from the service.

It should require no argument that posture such as is represented in Figs. 2, 4, and 6 is less good and represents less efficiency and alertness than Figs. 3, 5, and 7, and the fact should never be lost sight of that every individual like Figs. 2, 4, and 6 has the potential of that which is represented in Figs. 3, 5, and 7 which can be achieved by proper instruction.

Care of the feet. The importance of the part of the work that has to do with the care of the feet cannot be over-estimated, and can probably only be appreciated by those having served under conditions similar to those prevailing in this war. The proper fitting or adjusting of the boots or shoes, the correction of faulty habits of use, with the overcoming of elements of weakness, as well as the direction of the hygiene of the feet, are factors upon which depend the fitness for duty of large numbers of men who would be an encumbrance to the army but for such care.

In civil life the sizes of shoes commonly worn are as small as can be used without actual discomfort, and the socks worn are of such texture as to occupy but little space. Such covering may meet the needs of civil conditions, in which the physical activities are slight, but are not only inadequate for military needs but actually harmful, since action of the muscles of the feet is interfered with. Military activities demand the hardest kind of use of the feet, and to make this possible the shoe covering should interfere the least that is possible with foot action, while there should be ample room for warm soft socks to not only protect the feet from chafing but to furnish an absorbent for the moisture that will be developed. It has been found that practically all of the men in the army need shoes that are from a size and a half to two sizes longer than had been worn previously and with relatively narrow widths. Sizes as large as this are needed especially in the winter when the use of an extra pair of socks is expected. The common habit among the men of simply increasing the width of the shoe without increasing the length is to be carefully avoided since it results in added cramping of the toes and allows the feet to spread, thus increasing the potential of difficulty that exists naturally.

In fitting, the patient should stand with the shoe on, and there should be at least three-quarters of an inch between the tip of the great toe and the end of the upper part of the shoe when the full weight is borne upon the foot. With proper care in the fitting of the boots or shoes

large numbers of men will be saved for combat usefulness that otherwise would be discarded or assigned for other duty, and since this involves a vast amount of work, if it is to be carried out thoroughly, there should be a certain number of enlisted men trained for this special task who will work under the direction of the orthopædist.

While this work is important for men with relatively normal feet in order to lessen as much as possible the development of later weakness, it is of greater importance for the large number of men with weak feet, which inevitably are found in an army rapidly recruited from civilians without previous training. With proper care these men can be saved for full duty, and proper use of the feet will result in the development of strength in the weak part. When the common pronation, or inward sag of the ankle is present, it is obvious that hard use will result later in an increase of the sag with development of symptoms of strain. If, however, the heel of the shoe is raised at the inner edge a sufficient amount to correct this sag so that the two malleoli are equally prominent, the element of strain is eliminated and use will result in strengthening the structures so that ultimately the special adjustment of the shoe will be unnecessary. With a simple series of wedges the exact elevation that is required in a given case can be determined, but as a matter of fact three-eighths of an inch is so commonly the amount, that it can practically be taken as a standard. The necessary alterations can be made in an ordinary cobbler's shop, and to show the need of such work in one organization alone 100 pairs of boots a day have been so treated. For each man with whom this is necessary three pairs of boots are prepared, two of which are delivered to him while the other pair is carried in the quartermaster's stores. It is expected that by the time these three pairs are worn out the feet will have so strengthened that the special need will cease to exist, and with such provision the men should have lost no time from duty.

Besides this type of case, there will be a certain number of men with whom the feet are so markedly spread and the cuboid bone so completely displaced to the outside that they will not be controlled by the simple raising of the inside of the heel. For these it has been found practical to use a strap to correct the spreading and to draw the cuboid in under the tarsal bones. Such a strap can be made of soft leather or webbing or canvas and can easily be provided in the cobbler shop attached at the dépôt or replacement division. The strap should be twenty-two inches long, an inch and a quarter wide, and should fasten with a buckle, an inch wide, commonly designated as a trouser or suspender buckle. It should be applied as a figure-of-eight (Fig. 8) about the ankle and foot, and the buckle should be placed just behind the inner malleolus where it will cause no irritation. As the strap passes under the foot its desired position is just back of the base of the fifth metatarsal bone and over

the scaphoid, in which position the pressure is applied over the cuboid and the scaphoid, the two bones most displaced, and which must be replaced, before the proper strength of the foot is possible. With such a strap on, not only is marching possible but the effect of the support is to lead constantly to the correction of faulty position and in no way to interfere with the proper use or development of the muscles.

With a certain number of men the tarsal bones are in position and there is little if any pronation, but the front of the foot is badly spread with

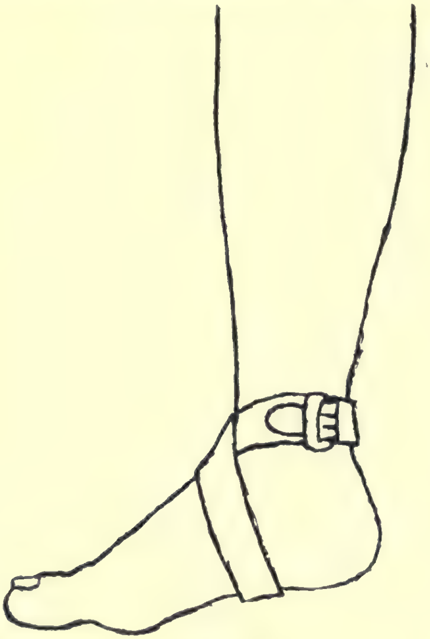

Fig. 8.

Fig. 9.

always more or less distortion of the toes. To meet this need a strap of similar material as that described above is provided and should be worn just back of the metatarso-phalanged articulations (Fig. 9). This strap, as also the figure-of-eight strap, should be worn over the sock. The buckle should be placed in the natural depression at the base of the fourth toe on the dorsum of the foot. With such treatment a shoe of average width will be possible, while otherwise a shoe much too wide for the rest of the foot would be required and naturally result in chafing, blisters, or strain.

With a very small number of men, because of periarticular thickening or osseous overgrowth, it will be impossible to secure full or satisfactory function without operation. The most common conditions in which this will be required are hallux valgus and hammer toe. For the former,

while the individual surgeon may be given some latitude in the selection of the form of operation, it should be fully appreciated that anything that shortens the length of the support for the arch upon the inner side must weaken the foot, and render it less good than is desired for marching. For that reason, the head of the metatarsal should be disturbed as little as possible, and instead of removing it entirely, as with the Heuter operation, nothing more than the prominence upon the inner side should be removed, while if it is necessary to do more in the correction of the deflected position of the toe, this should be accomplished by removing the base of the first phalanx. This should leave a freely movable toe with full length of the support for the inner side of the arch, and should give a foot that is ready for use in three or four weeks.

For hammer toe, the best operation consists of the removal by lateral incision of the distal two-thirds of the first phalanx. This shortens the toe enough so that it does not crowd the ends of the adjoining toes, as it otherwise would in straightening, and yet is long enough to prevent the lateral displacement of the adjoining toes, as would occur in case the entire toe had been removed. Amputation should practically never be performed. With such an operation the tendons are not disturbed, so that full control of the toe should result and active use should be possible in a week or ten days. With such an operation no after splinting is necessary and there can be no possible relapse of the deformity.

Standardized Splints, their Use and Method of Instruction. At a time when it is necessary to carry on activities on such a stupendous scale as is required in the present war, it becomes necessary to standardize such activities as much as possible in order to obtain the highest possible average in the character of the service. This principle has been followed in regard to the selection of the splints that are to be used for bone, joint, or other injuries in which such articles would be required, and a standardized list has been prepared and published in the *Manual of Splints and Appliances for the Medical Department of the United States Army*. To obtain the best results with injuries or conditions requiring the use of such apparatus, not only is it desirable to adopt the best forms of apparatus but also to see that proper instructions are given to those who are expected to use them. It is naturally expected that the members of the Medical Corps will have such familiarity, but since their use is of the utmost importance in the transport of the wounded, it becomes necessary to instruct the stretcher-bearers, ambulance-corps men, and hospital-corps men in the use of the apparatus, with especial reference to the application under emergency conditions. The instruction and supervision of these men has been delegated to the Division of Orthopædic Surgery, and not only should the technical use be appreciated by the men, but it should also be appreciated that all unnecessary handling

of the injured part without splinting should be avoided. It cannot be too strongly emphasized that a wound which may be of moderate seriousness may become greatly increased in importance by careless or incompetent handling in the transport to or from the hospital. A fractured femur, for instance, which is always serious, may result in conditions that are very grave, with loss of leg or life, if the bone fragments are not properly splinted. Hæmorrhage from torn vessels, or paralysis from damaged nerves, may be the result of injury during transport rather than the result of the original wound.

Thorough training of the stretcher-bearers in the application of such splints is not only important, but it should also be expected that such application will be made at the earliest possible moment. If for instance the splint can be applied before the man is put upon the stretcher, the chances of saving the life of the patient are distinctly greater than if even the least amount of transport without such splinting is allowed. To meet the needs of such work careful planning of the distribution of the appliances through the combat divisions, so that they will be most practically available for use, is essential, and this as well as the supervision of the work of the stretcher-bearers and ambulance-corps men has become a part of the work of the Orthopædic Division in the combat divisions, and the orthopædic surgeons for such work are now a recognized part of the army organization.

That this work has resulted in delivering the wounded man to the evacuation hospital in better condition than would otherwise have been possible there can be no question, and the work of the stretcher-bearers in applying the splints for the arm or leg injuries in 'no man's land' before any movement is allowed is deserving of the greatest praise.

POST-COMBAT

After wounds or injuries have been received the duty of the orthopædic surgeon consists in preserving as much of the tissue that has been injured as is possible and restoring the function of the part to the fullest possible extent.

To accomplish this the immediate protection of the part, so that there will be no unnecessary damage in transport, is naturally the first consideration, and is of the utmost importance, as has been indicated in the previous section. It should be clearly understood that the life of the patient may be lost from shock or hæmorrhage, or the limb be lost not directly because of the original wound but because of the unnecessary laceration of the tissues resulting from transport. To reduce such risk to the minimum and to prevent any unnecessary injury of the tissue, as well as to ensure the least possible suffering to the patient, the injured

part should be carefully splinted before transport is undertaken. For this anything that will limit or restrict movement in the injured part will be, of course, of benefit, and this can be secured in whatever way is possible in the given case. Fixation alone is of benefit, but the protection obtained in this way is less than is to be desired, since the muscular contraction that is still possible is capable of not only causing much pain but also of causing distinct injury. To accomplish the best results for the transport of such injuries, traction, which will control the contraction of the muscles better than anything else, together with the fixation provided by such apparatus, gives the best results and makes the handling of the patient for transport fairly easy. To make this possible and to easily secure both traction and fixation the apparatus that is of the greatest use is the Thomas splint, either with the full ring or with the modification having the half ring; it is by far the best apparatus for leg or thigh injuries, while the Thomas arm-splint with the ring hinged to the uprights is best for injuries of the arm. With these two models the injuries of the extremities can be so protected that transport is attended with but little suffering or increased injury. At the time of combat such apparatus should be carried well forward with the troops so that they can be quickly available for the stretcher-bearers and ambulance-corps men.

The preservation of function in the injured part, as well as the preservation of as much of the injured tissue as is possible, are the two features that give justification to the orthopædic surgeon for his position, and it should never be lost sight of that this responsibility begins at the time of the injury and not late in the course of the treatment. Too much emphasis cannot be put upon this feature, the need of which was constantly more evident as the war progressed. To prevent a man from getting a crooked leg, or a stiff joint, or from losing the leg, is much more to be desired, as well as much more economical for the nation, than to straighten the leg later or to attempt to restore motion in the joint, or to adjust the artificial member. To do this most perfectly the treatment should begin at the earliest possible moment.

For the cleansing of the wounds or the acute operative surgical part of the treatment, while the general principles should follow those recommended by the Inter-allied Surgical Conference, it should nevertheless be remembered that the removal of all unnecessary tissue should be most carefully avoided and that the condition of the part after the wounds have healed should never be lost sight of. It is of course desirable to cleanse the wound as perfectly as possible, and to have as little damaged tissue for possible sloughing or infection later; nevertheless, it is to be remembered that tissue may be removed unnecessarily with resulting loss of useful functions. It should be remembered that while primary closure of the wounds is naturally desirable, it may many times be better,

from the point of the greatest possible usefulness later, to make a less complete excision of doubtful tissue than would be desirable to justify primary closure, and follow the operation by use of the Carrel-Dakin solution for a few days, with the secondary or delayed closure of the wound later. Such a procedure, while not as brilliant perhaps as the primary suture, may nevertheless make the difference between helplessness and usefulness later. Without such procedure the removal of an entire muscle might have to be sacrificed, while with the less radical method enough of the muscle may be preserved to be of great assistance in future activities.

The same principle applies to the treatment of the bone injuries, and to ensure primary closure fragments of bone might have to be removed that could be preserved if the principles of secondary closure were followed. It should be remembered that every fragment of bone that can be saved is of value in the healing and ultimate strength of the part.

In case the wound is of such nature at the time of the beginning of treatment that closure is impossible or unwise because of infection, the Carrel-Dakin solution should be used until the sterilization is accomplished, after which closure in whatever manner is possible should be attempted. In the late cases with the chronic infections, the wounds should be thoroughly opened and as much actually diseased tissue removed as is possible, after which the thorough use of the Carrel-Dakin solution should be carried out until the tissues are in such condition that the evidences of infection have disappeared, when attempt at closure of the wound should be made. In the use of the Carrel-Dakin method of wound treatment it should be remembered that the success depends very largely upon the exact composition of the solution, and since there can be only five tenths of a per cent. variation in the strength of the solution, to ensure the desired result, the obviousness of the control of the dressings as well as of the solutions by skilled assistants is apparent.

With joint wounds if they are seen early in the first ten or fifteen hours after injury, the wound should be laid open, lacerated tissue removed in so far as is possible, as well as all foreign bodies, after which attempt should be made to close the joint with the use of active motion as early as is compatible with the wound healing. In case of infection free opening of the joint is desirable and sterilization with Carrel-Dakin solution is at times sufficient for the control, but under such conditions it many times is not possible to preserve the motion in the joint. At other times, after the joint is once thoroughly washed out, with the establishment of free drainage and with the encouragement of moderate active motion the infection is controlled and the drainage maintained. In such cases while moderate active motion may be desirable, passive motion should be avoided, since the active motion would be limited by the reflex muscular spasm as soon as the point of harmful irritation is reached, while with

passive motion this protective barrier might be broken down with distinctly undesirable results.

It should be a rule with all of the joint, bone, or muscle work that use or movement up to the limit of toleration is to be encouraged, since with such use all of the processes of blood and lymph flow, as well as innervation, are stimulated thereby, but the use should always be active and not passive.

The purely operative treatment for such conditions should always be carried out with reference to the result it will present when the man is ready for final discharge as a patient, and this implies continuity in the control of the treatment. Whether one surgeon directs the work all the way through or not is immaterial, provided there is some plan by which similar methods of treatment are followed as the man is moved from one service, or one hospital, to another. Some system of constant or radial control of the entire treatment is absolutely essential if the results are to be the best that is possible, so that from the time of the inception of the wounds until the completion of all treatment, the same fundamental plans will be followed. In this way good surgery in the front is supported by good treatment in the rear with benefit to all, while without such control excellent work at the front may accomplish little ultimately because of imperfect supervision later. Conversely, the best treatment at the rear will give a result much less good than was possible if the treatment at the front was not of the highest order.

To make the best of the wounded man or the wounded part is distinctly the function of the orthopædic surgeon, and whether the joint is damaged or the bone injured, or the muscles lacerated, or even the limb is lost, it is his duty to see that the man is returned to duty or his home with the least unnecessary handicap.

All of that which has thus far been mentioned has for its first reason the saving of men for the army, but it must be obvious also that the work at the same time helps the men as individuals. The preliminary training with the better habits of carriage must make for better general health, and since, with the careless, relaxed habits of carriage which have been so commonly seen are usually associated careless mental habits as well, the physical training which insists upon alertness of body also results in much greater alertness of mind. In regard to the post-combat work, not only does such work mean saving a great number of men for useful service in the army, but it makes amends to the men for the sacrifices they may have made, in so far as it is possible so to do. It must be obvious to any one that a man with an artificial leg can be just as useful for office work, or many details that require inactive service for the army, as the man who has not been injured. If the man is made to realize that he need not be considered unfit but is recognized as of use,

there probably is nothing that will preserve his morale and set a standard that should be carried into the conditions of civil life as much as this. In other words, the work here described, while primarily military and designed for the purpose of saving the men to the army, is at the same time most broadly humanitarian and represents a square deal to the man who has played squarely to the nation.

SIMPLE FRACTURES OF THE UPPER AND LOWER LIMBS

BY

W. H. TRETHOWAN

SIMPLE FRACTURES OF THE UPPER AND LOWER LIMBS

GENERAL CONSIDERATIONS

THE function of the limbs is mechanical, and the disability following a fracture is due to the transgression of mechanical laws. Regarded merely as living structures, the various tissues of the limbs are subject to the usual physiological and pathological processes obtaining elsewhere in the body, but apart from this their physiology is essentially mechanical. The structure or anatomy is determined by, and completely adapted to, mechanical uses. Since structure is subservient to function, exact reconstruction of a deformed bone presumably gives the maximum return of usefulness of the limb. But complete reduction of a fracture may be impossible or inexpedient, and it would therefore, as our first working principle, be more useful to aim at complete restoration of function. The simple machine forms exhibited in the body are the lever, and the wheel and axle, the latter being utilized in rotary movements. Leverage is mostly that of the third order, where, the effort being greater than the resistance, work is done at a mechanical disadvantage. Muscles have no great amplitude of motion, but make up for this deficiency by their great power. The mechanical disadvantage is compensated for by the compactness of the limb machine, and by proportionate advantage in increased speed of its moving parts. The essentials of a leverage system are : (1) rigidity of the lever, this being necessary for the transmission of weight or other force ; (2) the fixity of the fulcrum ; (3) unhampered motion of the lever about the fulcrum ; (4) the applied force—the effort or power ; (5) the resisting force—the weight. Hence we deduce those factors determining the ability of a limb segment to fulfil its function efficiently. The bone must be rigid in order to provide efficient lever arms for the acting forces ; no yielding must occur from weak or non-union at the site of fracture. The lever need not be straight, but its effect or ' moment ' will be given by the product of the muscle force into the vertical distance from the line of action of the muscle to the joint axis. In addition to the active function of leverage, the bones of the leg serve for weight transmission. The force of gravity is of less importance in the arm. The joint is the fulcrum, one articular surface forming the rigid point which transmits the ' reaction ' from the non-moving parts of the body or from the earth, while the other surface contains the rotation centre of the lever. Joint motion must neither be restricted by intra- or extra-articular

causes, nor be abnormally great from joint instability. Efficiency of the applied force or power demands a normal neuro-muscular structure and function. Conversely, and putting the matter briefly, limb disability resolves itself into two mechanical defects: (1) loss of power, and (2) alteration of range of movement—usually in the direction of restriction. The minor elements of disability, such as pain, swelling, and vascular changes, are also nearly always mechanical in origin or effect.

Certain physiological facts and pathological processes must be considered; the latter are mainly due to the alteration of skeletal mechanics which may follow a fracture. Wolff emphasized the adaptation of the external and internal configuration of bone to the function it subserves, and in his law states that altered function tends to modify the bone shape. Bone tissue is represented as a materialization of lines of force, an adaptation of connective tissue to stress, the production of compact and cancellous bone being determined respectively by common and diverse directions. This ossification or crystallization of the lines of force produces the small compact shaft and the large cancellous extremities. The delayed or weak union which is sometimes liable to occur in a fracture which has been 'plated' may be explained on the assumption that the stress is taken by the metal plate. Where end-to-end apposition of fragments is not obtained, the natural repair of a fracture is brought about by the eventual continuation upwards of the lower fragment, and along its line of direction. The now useless overhanging extremity of the upper fragment gradually atrophies and disappears, and the medullary canal later becomes continuous by the absorption of intervening compact tissue. If end-to-end apposition is present, but with angular alignment, the curved shaft becomes buttressed along the concavity, this tending to straighten the shaft in time. This reconstruction and adaptation of bone to altered circumstances is most marked in children. The ultimate effect of an incompletely reduced deformity resulting from a fracture falls principally on the joints distal to the lesion. As a rule the evil effect varies directly with the proximity of the fracture to the joint, and is twofold—the restriction of movement, and the disturbance of the axis of motion. The latter is of great importance in the leg, where, for reasons of equilibrium and gravity, the hip-joint must be more or less vertically over the foot, whatever the shape of the leg between these points. The knee, ankle, and tarsal joints are frequently seriously impaired as the late result of a fracture not directly involving them. One face of the articular surface is displaced relatively to the other, and on movement the joint surfaces jam and lock on account of their uneven bearing. Hence mechanical or 'traumatic' arthritis is set up, with its fixation, pain, swelling, and serious joint impairment. The knee- and ankle-joints must have horizontal axes. Adaptation of structure to altered function can occur

throughout life,. but is in inverse proportion to the age of the patient. It may not occur in adults to such an extent as would prevent the onset of very disabling traumatic arthritis. The various types of deformity which can occur as the result of a fracture may be arranged in the following order of severity of disability: fractures directly involving articular surfaces, with permanent displacement of fragments ; angular union when associated with overlapping and rotation of the fragments ; angulation with end-to-end apposition ; rotation ; shortening only.

The type of fracture in regard to the line of cleavage is of some importance in treatment. Indirect violence usually gives an oblique, spiral, or 'torsion' fracture, as a torsion strain is that least resisted by a bone ; and, unless violence is extreme, there is usually not much distortion of the limb, or injury of the soft tissues. Transverse and comminuted fractures are usually associated with more deformity and soft part injury, being the result of direct blows. The initial violence is the principal factor in the production of the deformity, which is subsequently maintained by the lateral distension of the longitudinal fascial and muscular ties, at first from hæmorrhage, and later from inflammatory exudation. Muscular spasm, which disappears as soon as the limb is splinted, is of little importance. The reuniting of the bony fragments is a gradual process depending on many conditions, and osseous union of some degree may occur as early as two to four weeks, or be delayed for months. A practical point arising in this connexion is the question when weight-bearing may be resumed after fracture of the lower limb. Weight-bearing should be delayed for some time after consolidation appears complete, as new callus is liable to yield under the strain, and permit the onset of deformity. Weight-relieving appliances are now very generally used for the first few months of walking after fracture of the long bones of the lower limb. The degree of consolidation can be estimated only by the feel of the union, the tenderness on pressure, and by the skiagraphic appearances of the line of fracture and the quality and amount of callus.

TREATMENT

A general account of the various methods of treatment will obviate repetition later. Arm cases will usually be up and about from the first, but lower limb fractures necessitate recumbency for several weeks, except under circumstances where early ambulatory treatment is called for. In cases where no open operation is needed, the initial deformity is corrected as far as possible when the case is first 'put up'. If the deformity is considerable, or much splinting and traction apparatus is to be applied, an anæsthetic is advisable. The splint system employed will usually include traction or extension, fixation or immobilization,

and suspension, and of these the traction is the most important in all cases with overlapping of fragments, particularly in the lower limb. All traction appliances for the lower limb belong to one or other of two groups, depending upon whether the counter-extension is supplied by the weight of the patient's body, or by the thrust of the splint on the tuber ischii and buttock tissues. The two methods cannot be combined. The bed itself is included in the splint system of the former, but not in the latter. Where the body weight is utilized, the effect is augmented by raising the foot of the bed and depriving the patient of pillows. The compound war fractures necessitated the use of various traction appliances, such as steel pins, screws, glue and gauze, callipers, &c., but nothing is nearly so efficient in simple fractures as the adhesive strapping stirrup when correctly applied. Traction may be either *fixed*, as when the stirrup is fastened to the end of the bed, or it may be *movable*, as when a pulley and weight are used. The latter is more efficient, as well as more comfortable for the patient, and the stirrup should be first fastened to the splint, so that the weight exerts traction on splint and leg together. Suspension of the splint, just to clear the bed, by one or more cords from either end passing through pulleys on an overhead framework to counterpoises, adds greatly to the comfort of the patient, and to the ease of nursing; this may be applied to any splint. The fixative appliances or splints now generally adopted are: frames of stout wire or small round iron, such as the 'Thomas bed-splint', combined with pads and flannel slings; sheet metal of sixteen or eighteen gauge, cut to any length and width, the so-called 'fracture splints'; plaster of Paris; and closely fitting or moulded leather. The open or skeleton splints allow free access to the limb, and are thus convenient for regulation, and for the early utilization of physiotherapy. For the latter reason provision should be made for early joint movements without the necessity of removing the splint. In most lower limb fractures the Thomas bed-splint is much the best appliance, whatever method of traction be employed. Should it be required to put up the case with the knee flexed, it is advisable not to bend the splint, but to attach the additional movable piece for the lower leg. Plaster of Paris is useful generally only in more distal fractures, such as those of the leg and forearm, and then only when, end-to-end apposition being present, it is desired to prevent angulation. It can be made removable for physiotherapy, and lends itself to a variety of design in smaller splints. Plaster has some disadvantages; it must be renewed as a rule if regulation or further correction is required; if metal joints are incorporated the splint is liable to be very heavy and cumbersome; large plasters, such as spicas, are very irksome to adults, and it is an expensive, laborious, and tedious treatment if early renewal is required. Traction in fractures of the long bones of the lower limb cannot con-

veniently be combined with plaster of Paris, as the risk of pressure sores is too great, however carefully the plaster be applied. Where a closely fitting splint is required, e.g. in ambulatory treatment, it is preferable to take a plaster cast of the limb, and substitute the fixation plaster by a removable moulded leather splint, hinged with steel, as soon as it can be made. Sheet metal splints are very adaptable, alone or in combination with other splints; they may be made angulated, as in a posterior elbow splint, or a 'club-foot shoe', or racked and jointed as in a Mackintyre splint. The ambulatory weight-relieving appliance is used in all injuries and diseases of the lower limb, including those of the hip-joint, where motion and walking would be advantageous but weight-carrying harmful. Weight is transmitted from the tuber ischii and the buttock to the boot through the side steels of the instrument. Sliding mechanisms on the side steels must be provided to regulate the length of the splint, so that it may be about half an inch greater than that of the leg. When the patient puts weight on the calliper ring or 'thigh bucket', the heel of his foot should be raised from the heel of the boot by half an inch, to avoid the transmission of weight through the heel of the foot and thus through the leg. Two patterns of this appliance are in use. The simpler and cheaper is the 'Thomas calliper', a modification of the Thomas knee splint. The splint is unjointed, but foot movement is permitted by a round socket in the heel of the boot. The other pattern is the Hessing type of appliance, with the thigh bucket made of moulded leather. A ring-catch joint is supplied at the knee, and also an ankle-joint. This appliance has advantage over the calliper in its more comfortable seat, and greater control of the whole thigh, as well as permitting flexion of the knee when sitting.

The surgical necessities of the war have been a great stimulus to the more efficient treatment of fractures by manipulative measures, but in certain cases a satisfactory reduction of the deformity and fixation of fragments will be obtained only by open operation. Exploration of the fracture and reduction of deformity may be quite sufficient, no internal splint, such as a bone graft or metal plate, being required. Such cases are those with extensive displacement in a fracture near a joint, or where stirrup and weight traction is inapplicable, or, again, where a long spiral fracture exists. If end-to-end apposition cannot be maintained after open reposition, some internal retentive means, such as screws, pegs, wire, bone graft, or metal plate, must be employed according to circumstances. With efficient external splinting, foreign material left in the wound for retentive purposes may be reduced to a minimum. In the future the more extensive use of autogenous bone grafts, or sterilized foreign bone, will limit the use of metal plates for fixation purposes; but when the retentive agent must take a great strain, then either a metal

plate must be employed if the operation is done early, or the operation must be postponed until traction and other means have been adopted for two or three weeks to reduce the deformity and strain to the minimum. Operative interference requires for its success asepsis, and absolute fixation if any foreign material is introduced. The use of a tourniquet is inadvisable, and bleeding points should be compressed with strong forceps which remain on throughout the operation. The skin edges must be well towelled off. Swabs should not be handled, nor should the working ends of the instruments. Blood clot and lacerated tissue are cleared from the seat of fracture, and if much overlapping exists the bone ends can be apposed by angulating the fragments with the big bone forceps. On no account should the fragments, graft, metal plate, screws, &c., be handled. As little catgut as possible should be used. For the skin suture continuous fishing gut, or better, Michel's clips, may be employed; and after the operation the limb should be well splinted to avoid unnecessary strain on the fracture.

FRACTURES OF THE UPPER LIMB

Clavicle. As a rule the clavicle is fractured just to the outer side of its mid-point, or somewhat nearer the shoulder-joint, and from an indirect strain due to falls on the arm or shoulder. The line of cleavage is oblique, and slight over-riding of the fragments is usual. Angulation is forwards, and some depression of the outer fragment occurs on account of its coracoid attachment and the weight of the arm, but no great deformity is possible. Union always occurs and complications are rare. The most satisfactory ambulatory method of treatment is that of Sayre—in which, the middle of the upper arm being fixed with strapping well backwards and close to the chest wall, to form a fulcrum, the outer clavicular fragment is extended outwards, backwards, and upwards by drawing the elbow and forearm strongly inwards, forwards, and upwards across the front of the chest by means of a second broad band of strapping. Union is firm in about four weeks, but the suspension should not be discontinued too early on account of the strain caused by the weight of the arm. Where a perfect anatomical result is urgently desired, for cosmetic reasons, the patient should be confined to bed for three weeks, and lie flat on the back without pillows, the correction being assisted, if desired, by a webbing brace which holds the two shoulders together from behind, after the manner of the 'three handkerchief' method. The clavicle does not well lend itself to operative correction and fixation, as it is so subcutaneous; any fixative wire or plate is liable later to ulcerate through the skin, unless it can be applied to the posterior surface of the bone.

Scapula. Fractures of the scapula result from direct injury. Those of the body of the bone are usually unassociated with any displacement, and are therefore in themselves of little importance. The acromion process is occasionally broken off, but it is more common for direct injury to produce dislocation of the acromio-clavicular joint. Fracture of the neck of the scapula, with comminution, and involvement of the shoulder-joint, can occur with excessive violence, but is rare. The fragments are satisfactorily immobilized by control of the upper arm.

Upper End of Humerus. Fractures of the upper extremity of the humerus are of importance in their relation to the shoulder-joint, and have hitherto been classified as fractures of the ' anatomical neck ', where the line of cleavage is mainly intra-articular, and those of the ' surgical neck ', where the break is immediately below the tuberosities. Skiagraphic observation, however, shows that the line of infraction may run in one or more directions in any part of the upper end of the bone. Perhaps the most constant type is that of the surgical neck, with a transverse fracture from one and a half to two and a half inches below the top of the greater tuberosity ; adduction deformity is usual, the upper end of the lower fragment being displaced inwards towards the axilla, and forwards. In the intra-articular fracture of the anatomical neck the line of cleavage is more likely than not to be extra-articular in part, as it often runs down obliquely on the inner side of the bone, producing a spur. The upper fragment formed by the articular head is liable to be rotated into any position, and dislocated from the glenoid surface. The original fracturing force may cause partial impaction of the lower fragment into the head of the bone, with comminution or splitting up of the latter into several pieces. Sometimes the greater tuberosity alone, and more seldom the lesser, may be split off and displaced, the greater tuberosity riding up and subsequently interfering with abduction of the arm through impaction of the displaced piece against the acromion.

Regard for the eventual function of the shoulder-joint principally determines the treatment. Extra-articular deformity can be easily corrected by manipulation under anæsthetic, the difficulty being rather in the maintenance of the correct position. No residual deformity, such as internal angulation, can be permitted, however slight, and even impacted deformity should be reduced. Union of fragments always occurs, except in some cases where the articular head is separated. A rotated or dislocated intra-articular fragment will very probably require reposition by operation ; this is easily done by the usual anterior deltoid incision, but there is some liability to recurrence of displacement. If this recurrent displacement cannot be prevented by one or two screws driven through the tuberosity, the head of the bone ought to be removed, but resection more extensive than this must be avoided. Anything more than the slightest

displacement of the greater tuberosity must be remedied by operative correction, and fixation with screw, peg, or suture. For mere fixation in fracture of the surgical neck, it is sufficient to strap the upper arm to the side of the chest, using an axillary pad to prevent adduction of the upper end of the lower fragment. If extension also be required, the distal part of the forearm can be suspended in a sling, and the weight of the arm utilized to exert traction. This arrangement will not interfere with massage treatment, which should be started at once. As union occurs so readily movements may begin after the third week.

Shaft of Humerus. The humeral shaft may break anywhere along its length, but most commonly about its middle or just below. The line of fracture is usually transverse, or oblique with comminution. Lateral displacement, with projection inward of the lower fragment, is the common deformity. There may be an initial shortening, but this soon disappears under treatment. The alignment in one plane is easily obtained, the real difficulty in the treatment of fracture of the shaft of the humerus, as in the shaft of the femur, being to procure end-to-end apposition. It is somewhat difficult also to obtain thorough immobilization of fragments in the more central portion of the shaft. These are the reasons why fractures of the shaft of the humerus are credited with a proclivity for non-union, a danger very much over-estimated. The difficulty of control of the fractured ends is due to the existence of a complete sheath of soft tissues, and is increased when there is much swelling of the soft parts. A comminuted oblique fracture is more easily controlled. Splinting for upper-arm fractures is notoriously unsatisfactory, but for general use the best appliances are the shoulder or upper-arm 'abduction splint', made of light sheet metal or wire framework, and the 'arm Thomas' with padded ring through the axilla and around the shoulder; both splints are bent to keep the forearm at right angles with the upper arm. The shoulder abduction splint will be useful when it is desired to bring the lower fragment into line with the abducted upper portion; it gives a good fixation, and can be arranged to exert some traction. It is, however, rather heavy and cumbersome, and makes skiagraphic examination difficult. The arm Thomas is light, and will be used where the vertical position of the upper arm is desired. The crank on the splint at the bend of the elbow allows the application of stirrup traction, but usually very little more than the weight of the arm can be borne as a traction force; otherwise the counter-pressure of the padded ring in the axilla causes œdema of the arm. It is suspended from the shoulder either tightly or lightly according as it is desired to take counter-pressure from the axilla or not. This splint lends itself well to the control of lateral displacement of the fragments by lateral and antero-posterior flannel slings, and the regulation, as well as the initial reduction of the deformity, should be done under the

fluorescent screen. When no deformity exists, a simple removable posterior angular splint, which may be of metal or plaster of Paris, will suffice. Complete fixation in plaster of Paris is undesirable, as neither is the fixation good, nor does the method allow subsequent control of the position. The method of putting up a fracture of the humerus by keeping the elbow fully extended, and exerting traction on the forearm and hand, is to be condemned on account of the awkwardness in getting about, and the subsequent difficulty in flexing the extended elbow-joint. Ambulatory treatment is customary in fracture of the humerus, but if the patient is confined to bed a good traction can be made by pulley and weight acting through a well-applied stirrup on the lower part of the upper arm. Whatever splint is used should be maintained for five or six weeks, but careful movements of the shoulder and elbow-joints can be commenced at the end of a fortnight. Operative interference may be desired in order to determine reduction, with or without fixation of fragments. The best approach is on the external or antero-external surfaces, and the musculo-spiral nerve presents the only difficulty. If fixation is decided upon, a metal plate or autogenous bone-graft should be used, and the fixation must be complete. Merely wiring the fragments together is likely to be unsuccessful on account of the liability to incomplete fixation. A metal plate may cause delay in consolidation. Where the fracture is less than one and a half inches above the elbow-joint, successful internal fixation by plate or graft is very difficult. In the writer's opinion, an intermedullary graft about four inches in length taken from the patient's own tibia, and so applied that no gap is left between the upper and lower fragments of the humerus, is the ideal internal fixation means for fracture of the humeral shaft.

Lower End of Humerus. Fractures of the humerus in the vicinity of the elbow-joint result from either direct or indirect violence, and if in part intra-articular are very liable to lead to some permanent disability on account of the intricate formation of the joint. The existence of the various fossæ renders the lower end of the humerus structurally weak, and the line of cleavage is very prone to pass through one or more of these hollows, which may later become permanently filled with callus. Usually the line of fracture is mainly transverse, with the tendency to the formation of a spike on one or other borders of the lower fragment. The transverse fracture is often converted into a **T**- or **Y**-shape by a vertical cleft running into the joint ; the latter may separate off one or other condyle, or divide the capitellum from the trochlea, or even split the trochlear surface. In other cases merely a condyle is chipped off, with the rest of the humerus intact ; or a piece of the capitellum is separated. Various conditions of deformity may occur ; as a rule the lower fragment is carried backwards, or backwards and outwards. Sometimes in **Y**-shaped

fractures the fracturing force separates the inner and outer parts of the lower fragment, thus increasing the width of the joint.

The general rule for the treatment of all fractures in the region of the elbow-joint, except fracture of the olecranon process, is to put up the limb with the elbow-joint fully flexed. Usually a splint is unnecessary, the supinated forearm being fixed to the upper arm and shoulder with strapping and bandage, and the whole arm lightly fastened to the chest in a sling. The advantages of the flexed elbow position are several: it gives the most complete anatomical reposition of fragments and the best fixation; it favours the retention of the more important flexion function of the joint; and it co-operates with gravity in the subsequent restoration of function. To correct the initial deformity, strong traction is exerted on the forearm with the elbow fully extended, while the surgeon manipulates the joint, forcing the upper fragment backwards with the thumb, and pushing the olecranon and lower fragment forward with the fingers. While traction on the forearm and pressure on the fragments are well maintained, the elbow is firmly and slowly bent until flexion is complete, with the forearm supinated as much as possible. On account of the liability to Volkmann's ischæmic paralysis after injuries to the elbow in children, it is inadvisable to leave any pad in the bend of the elbow, to have any constricting band whatever about the joint, or to put up the elbow in too extreme flexion; neither should the manipulation be repeated unnecessarily, nor done with undue force. The possibility of Volkmann's contracture, the special liability of injuries in the elbow region to be followed by traumatic myositis ossificans, the possibility of injury to the ulnar nerve, and the tendency to subsequent permanent restriction of movement from undue callus formation in the fossæ, should lead us to treat fractures in the vicinity of the elbow-joint with the greatest respect. Open operation for the correction of deformity is not often required, unless there is lateral separation of the fragments, or a condyle does not fall into its true position, in which case the judicious use of a single screw or a suture may complete and maintain the correction. Union is usually satisfactory except for the tendency to redundant callus formation in the fossæ, with its evil effect on the subsequent restriction of motion. The internal condyle is liable to unite only by fibrous tissue, and give rise later to chronic local pain and irritation of the ulnar nerve. Injury of the elbow-joint may at times cause small particles of the articular edge to be broken off, the fragments subsequently becoming loose bodies in the joint. Usually these are only one or two in number, but in rare cases they proliferate until as many as fifty or sixty may be present, of firm osseous structure, and as large as cherry stones. Single loose bodies may give trouble by causing locking of the joint, or irritation of the ulnar nerve; but when many are present they become

deposited in synovial pouches, and cause singularly little disability other than weakness. In the subsequent treatment of lower humeral fractures, the flexion position is maintained from ten to fourteen days; the forearm is then lowered a few degrees, and, while the wrist is retained in a 'collar and cuff' sling, the patient is encouraged to do active movements of the elbow within the limited range allowed. A few additional degrees of freedom are permitted every few days by lengthening the sling a little, until the arm is fully extended, the active movements being continued regularly meanwhile. Should the elbow tend to stiffen during the time it is being brought down, and the patient unable to obtain actively the initial degree of flexion, the inference is that the joint has not been rested sufficiently long; in this event the full flexion position must be restored and maintained for another week or so, after which the gradual mobilization method is begun again. Passive movements need not be started before the end of the third week, and, even then, should be confined to one single movement in each direction of flexion, extension, pronation, and supination. On no account must the fracture be rocked by the 'pump-handle' method of passive movement. Massage, in contradistinction to movements, can be used from the first, as far as the joint is accessible. Two methods of treatment in the later stages of fracture about the elbow are mentioned in order to be condemned. The one is movement under an anæsthetic, which is not only useless, but absolutely harmful, as it leads to still greater permanent restriction of the joint movement. The other is the attractive proposition of removing excess of callus from the fossæ by means of open operation; the operation is easy, and the immediate effect on the table is as encouraging as its results a few weeks later are hopelessly bad. The removal of obstructive spurs of bone is quite another matter, but even this must be done with discrimination and care, and only in selected cases.

Upper End of Radius and Ulna. The special injuries in this region are these of the olecranon process, the coronoid process, and the head and neck of the radius. Transverse fracture of the shafts of the radius or ulna, or both, in the upper end of the forearm rarely results from simple injury, and is best considered under fractures of the shaft. Fracture of the *Olecranon* process involves the elbow-joint, and occurs usually at the base or weakest part of the process; it results from direct injury, and is common in later adult life. The line of fracture is transverse, or may be oblique, and runs from the articular surface of the base of the process backwards and upwards towards the attachment of the triceps. The amount of separation and extravasation depends on the extent of the injury to the aponeurosis of the forearm, but is usually not great. The fracture may be treated by an extended position of the elbow-joint for two or three weeks, after which active movements may be

commenced. The elbow can be brought to a right angle about four weeks after the injury. The fear of fibrous union and a permanent gap between the fragments, and the ease of fixation by open operation, are the reasons why this condition is so frequently operated upon. In those cases, however, where no operation has been done, union is almost always satisfactory, and the occurrence of fibrous union, with subsequent stretching and gap, is far more rare than might be anticipated. As in an old fractured patella, when a gap occurs the permanent joint disability is very slight. The skin incision is curved to avoid the site of fracture, and the best fixation is by means of a wire passed transversely through each fragment and twisted up on one side. The method of the long screw driven along the axis of the bone from the distal end of the olecranon is not good, as it does not prevent rotation of the process. Fracture of the *Coronoid* process may result from backward dislocation of the elbow-joint, and its importance lies in its liability to be the cause of an obstructive spur or of traumatic myositis ossificans. It should be treated by the complete elbow flexion method. Open operation for the removal of the process or excision of spurs should be undertaken only after mature consideration and experience, as the region is very difficult of access, and the results often disappointing. Fracture of the *Head* or *Neck of the Radius* is not uncommon. No room exists in this part of the elbow-joint mechanism for even slight displacement, or for excess of callus, and either of these may give considerable pain and mechanical disability in flexion of the elbow-joint and rotation of the forearm. Treatment is by the full flexion position, and the arm should be rested for several weeks. Early movement is contra-indicated by the desire to limit excessive callus formation. Should mechanical obstruction supervene later, the head of the radius can easily be removed by a posterior incision, and the good result of the operation is a sufficient justification.

Shaft of Radius and Ulna. Fractures of the shafts of the radius and ulna usually occur in the middle of the forearm, and although either bone may be broken, fracture of both is much more common. The line of fracture is transverse, but comminution is infrequent, and the two bones may break at the same or different levels. The resulting deformity is such that the fractured ends look towards the dorsal surface of the forearm, with perhaps overlapping of the fragments, and pronation of the forearm below the fracture. The normal parallel position of the bones in supination is disturbed, the raw ends of the fragments tending to approximate to one another. This may lead later to vicious or cross-union, preventing rotary movement of the forearm, but this danger is far less in simple than in compound fractures. While the ulna tends to angulate towards the extensor surface, the radius, in addition to slight angulation, is liable to have its lower fragment rotated into pronation relative to the upper

fragment, and, unless this be corrected, the subsequent range of supination of the forearm is impaired. As a rule, the forearm and hand should be splinted in complete supination, the elbow being flexed to a right angle to allow the upper arm to act as the counter-rotation, while the supination is controlled by the thenar side of the palm and wrist-joint. The most serviceable splint consists of dorsal and palmar malleable iron strips, of two or three inches width and slightly curved on the flat, and embracing the elbow as well as the wrist-joint. Alternatively, the forearm and the palm, together with the lower half of the upper arm, can be enclosed in plaster of Paris, which is subsequently cut up along the inner and outer borders, and made removable. These splints allow the use of pressure pads at desired points. Should angulation backwards be difficult to control, the arm is best fixed for a week or more with the elbow-joint fully extended, but this position is very tedious. If traction is desired in cases with over-lapping of fragments, the best method is by the plaster pad and wire splint now used so successfully to correct flexion deformity of the fingers. With the elbow flexed to a right angle, the plaster pad lies along the flexor surface of the forearm. Its turned-up and well-padded proximal end exerts a counter-thrust against the lower half of the upper arm, while from the distal end of the plaster, which reaches to the palm, a wire loop extending some inches beyond the finger-tips serves as the point of attachment for pieces of rubber elastic carried from strapping stirrups on the hand and fingers. Open operative treatment is of no avail unless internal fixation is carried out. Access is by radial and ulnar lateral incisions, or by a median skin incision on the extensor surface, with lateral incisions between the muscles. A 'four-hole' metal plate on each bone can be easily applied, and will give perfect apposition and correction, even when overlapping is present. Sometimes it may be sufficient to fix one bone only. Metal plates are liable to cause some delay in union, and therefore physio-therapy must be carried out with care, but union is subsequently good. When there is no strain in the corrected position, and when both bones are broken, intermedullary grafts from the tibia give unsurpassed results ; if one bone only is broken, the graft is slotted into one fragment and impacted into the medullary canal of the other. In the treatment of cross-union resulting from forearm fracture, the two points essential for the success of the operation are : the insertion of a flap of subcutaneous fat between the two bones, and the avoidance of any movement whatever of the forearm, active or passive, for three months.

Lower End of Radius and Ulna. Fractures in this site are particularly those of the radius in the vicinity of the wrist-joint, more especially the varieties of Colles's and associated fractures. These are caused by blows and wrenches exerted on the hand, and are prone to occur in elderly

females, and in chauffeurs and other mechanics. Children frequently sustain a similar fracture, the so-called separated epiphysis. The fracture is usually about half an inch from the articular surface, but may be more or less. Comminution, impaction, displacement, can occur severally or together. The common deformity is that in which the articular fragment is displaced backwards and radially, as well as being rotated backwards and somewhat crushed, the line of cleavage extending transversely across the lower end of the radius. The hand is displaced with the lower radial fragment, and the characteristic spoon-shaped deformity of the lower forearm results. With the break in the radius there is usually a fracture of the ulnar styloid, which is separated at its base, or a tear of the lateral ligament on the ulnar side of the wrist. Sometimes the radius is not broken quite across, but merely a portion of its styloid process separated. There is less tendency to displacement when fracture of the radius occurs more than one inch from the wrist-joint. The deformity following a Colles's fracture must be reduced, even if not seen until some weeks after the accident ; otherwise permanent weakness of the wrist and deficiency of grip will ensue, as well as restriction of wrist movements, and pain. The reduction is easily effected by strong flexion of the wrist, combined with radial abduction. The subsequent retention of the corrected position is not difficult, and may be maintained by anterior and posterior malleable metal splints, which keep the wrist-joint slightly flexed, and extend as far forwards as the metacarpo-phalangeal joints. Sometimes it may be necessary to keep the hand in radial abduction, in which case a removable splint made of plaster of Paris is preferable. Early movements of the finger-joints should be encouraged, but the splints should be retained ten or fourteen days or more. A skilful masseuse may be allowed to give active movements and massage from the very beginning with advantage, if care be taken to see that the deformity does not recur nor the fracture be rocked.

Carpus, Metacarpus, and Phalanges. Severe wrenches of the wrist, more especially when the joint is violently extended, are liable to cause fracture of one or more of the carpal bones, and sometimes also their dislocation. The scaphoid is most prone to injury and commonly breaks transversely into two more or less equal parts ; in other cases the dorsal border of the bone may be chipped. The fragments are very liable to remain ununited. The os magnum and the semilunar are also sometimes fractured, and the latter bone may be wholly dislocated from its carpal row, twisted on itself, and displaced to the front of the wrist-joint, forming a projection under the flexor tendons. The diagnosis is made on the local swelling, tenderness, and pain, in the case of a fracture of the scaphoid, and is confirmed skiagraphically ; the hollows on the radial aspect of the wrist-joint become obliterated, and the site of the scaphoid is tender

on both surfaces. Later, some disability is liable to be permanent, consisting of various degrees of restriction of movement, pain on forced extension, cracking or grating on movement, and a feeling of weakness in the wrist and in the power of grip ; sudden pain may occur and the joint ' give way '. A sprain of the wrist which does not clear up in the usual time is probably complicated by an intracarpal fracture. In the treatment of the acute condition, manipulation under anæsthetic must be done when there is any dislocation of a fragment or of a whole bone ; any persistent displacement will seriously hamper the joint function. If manipulation is unsuccessful, an early open operation must be performed to remove the deranged fragment. The scaphoid is best approached through a dorsal incision, when strong flexion of the wrist will give good access. A semilunar displaced to the front of the joint can be totally removed by cutting down between the flexor tendons. Early operation other than to correct displacement is contra-indicated. Conservative treatment will require a week or two's rest on a splint, in the attempt to consolidate the fragments, followed by early gentle active movements and massage, but passive movement must be avoided. If later there be permanent restriction and pain, the removal of a portion or of the whole of the scaphoid may be beneficial, but more often than not such operative interference proves to be injudicious. The metacarpal bones may be broken in the shaft from direct violence in simple injuries ; there may be some deformity in the direction of angulation towards the extensor surface, the deformity often being more than the disability. More important is the fracture of the first metacarpal near its base. Fracture of the shaft of a phalanx is liable to result in angular deformity towards the flexor surface, which unless corrected would cause apparent hyperextension of the finger, and deficiency of flexion range. Small fragments may be chipped off the head or the base of a phalanx, with subsequent tedious interference with the joint movement, and sometimes causing deviation of the terminal phalanges from the centre line of the finger. Fractures of the bones of the hand can usually be successfully treated by simple malleable metal splints and wool pads. To maintain the proper alignment of a phalanx, it may be necessary to fix the fingers more or less flexed ; a good position is one in which the hand is bandaged up as a fist without any splint.

FRACTURES OF THE LOWER LIMB

FRACTURES OF THE PELVIS

Apart from those of the acetabulum, with their mechanical results on the function of the lower limb, fractures of the os innominatum are usually of no serious importance except in so far as they are complicated by injury of the pelvic viscera. Fractures of the pelvis due to simple injury are relatively uncommon, and are the result of crushes and other direct violence. The rami of the pubic bone and ischium are liable to be broken at their thinnest portions ; the crest of the ilium may be separated in part in the region of the anterior superior spine ; and sometimes the ilium is fractured transversely above the acetabulum. A fracture may involve the rami bilaterally, and the whole of the body of the pubis thus be separated. As a rule, displacement of fragments is not great, union is satisfactory, and, if there be no visceral complications, recovery is uneventful. Fracture of the acetabulum is due to severe force transmitted from the trunk or leg, and involves the upper and posterior rim of the socket, a portion of which is displaced upwards and backwards ; it may be complicated by a partial or complete dislocation of the hip-joint occurring at the same time. In other cases, where acute dislocation is the chief clinical feature, some chipping of the acetabular rim is nearly always present. The importance of fracture of the acetabular wall lies in the liability to varying degrees of subluxation of the hip-joint which may occur later when the patient again assumes weight bearing on the leg, or to the onset, at a still later period, of disabling ' traumatic ' or mechanical arthritis. The displacement upwards of the head of the femur may be of any degree, even to complete dislocation on to the dorsum ilii. In complete dislocation the characteristic limp occurs, and in the lesser subluxations and traumatic arthritis conditions flexion and adduction deformity of the hip-joint results, with pain, fatiguing compensatory lumbar lordosis and raised pelvis, cracking and grating on movement, real and apparent shortening of the limb, and wasting and weakness of the muscles about the joint. Also, in time, flattening of the head of the femur, and osteophytic outgrowths from the head and acetabulum, add their share in limiting the joint movements and increasing the disability. Another, and much rarer, acetabular fracture is that in which the head of the femur is, as the result of direct violence on the trochanter, driven through the bottom of the acetabulum into the pelvis, the socket being broken stellately, but the head of the femur uninjured (the so-called central dislocation of the hip). Acetabular fractures occur in younger adults, whereas in older subjects the neck of the femur is more prone to give way. After the immediate reduction, under

an anæsthetic, of any co-existing dislocation of the hip-joint, the treatment will be directed to provision for the ultimate function of the joint, more particularly in preventing subsequent subluxation. Weight and stirrup traction, increased rapidly to twenty or thirty pounds, over the well-raised end of the bed, is the first essential. It will add to the comfort of the patient, and assist nursing, as well as allow early movements, if the whole leg be placed in a Thomas bed-splint, and slung counter-poised just clear of the bed, as in the 'Balkan' arrangement. The splint should be attached to the extension stirrup, and the counter-pull exerted by the patient's body-weight, no thrust being taken on the tuber ischii. Care should be taken to avoid more flexion of the hip than necessary, and the easy position of the slung limb should be that of the greatest possible abduction. Massage can be done from the first, and movements begun early without removing the splint. The traction must be maintained from six to eight weeks, during which the stirrup, which extends from the ankle to the groin, may require renewal. The patient may be allowed up at the end of ten or twelve weeks in an ambulatory weight-relieving apparatus, either a calliper splint, or a Hessing appliance, which should be worn from six months to a year or more.

UPPER END AND NECK OF FEMUR

It has been customary to classify fractures in this region as 'intra-' and 'extra-capsular' on account of the distinguishing clinical features, etiology, pathology, and treatment. Intracapsular fracture, or fracture of the neck of the femur, is common in elderly subjects, and results from the indirect violence due to a fall in which the leg is twisted. The neck of the bone breaks either transversely at its narrowest part, or obliquely, with a spike projecting downwards from the femoral head. The initial shortening is about three-quarters of an inch, and the limb lies everted and helpless. Extracapsular fracture is due to a direct blow on the upper and outer part of the thigh, and exhibits any degree of splitting or comminution of the trochanteric region; longitudinal fragments may be split off from the upper few inches of the shaft, with perhaps as many as seven or eight separate fragments; the neck may be broken at its base; and there may be impaction of fragments. The shortening and deformity depend on the degree of injury. Usually the limb below is adducted, the fragments of the great trochanter abducted, and the neck, if separated, is at right angles with the general line of the upper shaft. As in all complete fractures of the femur, the treatment consists of traction, immobilization, and suspension; and the most generally useful splint is the 'Balkan' arrangement, described elsewhere, combined with 'weight', rather than 'fixed', traction. The limb below the fracture should be abducted to such an angle as will restore the natural shape

and alinement of the whole femur, a foot-piece being provided to control the rotation. When angulation and impaction are present, initial correction should be made under an anæsthetic, and the fragments freed and the deformity reduced as far as possible. The weight traction must be as great as the patient can stand. Elderly subjects must not remain in bed for more than the minimum period—perhaps only a week or so—and the treatment should quickly be made ambulatory ; the reason for this is not the fear of pneumonia, but the risk of loss of ' moral ', so to speak, or of the desire to help themselves to be about again. Younger patients may be kept in bed for the allotted period of eight weeks, as the prospects of good union and correct anatomical reposition are more favourable. Efficient traction will reduce the shortening completely, or to practically nothing. The union of a fracture of the neck of the femur in elderly subjects is generally considered to take place by fibrous, and not osseous, tissue, but the final result is much more often a pseudo-arthrosis, or false joint, at the site of fracture ; but in spite of this, however, the functional result is very good if the ambulatory weight-relieving splint is worn from six to twelve months, the leg showing no sign of progressive shortening after the appliance has been discarded. In extracapsular fractures, which unite by bone, the calliper splint should, as a rule, be used for the first three months after the patient gets up, as young bony union is liable to yield under the stress of weight-bearing if there is the least residual deformity. This rule applies in a general way to all fractures of the lower limb. When no initial shortening exists, especially in transverse fractures, it might be desired to get the patient up and about early in a plaster-of-Paris spica, but the objections to this method are its tediousness in the case of adults, and the difficulty of combining it with traction, or of utilizing physio-therapeutic treatment. The use of the double abduction splint, a modification of the Thomas double hip-splint, is now almost obsolete ; as a splint it is good, though clumsy, but as a traction appliance it is unsatisfactory. The unsuspended Thomas bed-splint, with fixed traction, and the counter-thrust on the tuber ischii, is unsatisfactory for high femoral fractures, and is an uncomfortable traction appliance. As regards open operative treatment, it has at times been not unusual to endeavour to fix the head of the femur by one or more long screws driven in through the great trochanter along the axis of the neck of the bone, but the method is now almost universally discarded, on account of the difficulty of uniting the fragments in perfect position ; also, the tendency to bony union is not thereby increased, and the functional result of non-operative treatment is quite as good. Axial bone grafts have been used instead of screws in some cases. In juxtatrochanteric fractures, operative fixation is very rarely called for, as the bone is often so fragmentary, and the position and shortening can

be so well corrected by conservative means ; a purely lateral displacement, however, may demand metal plate and screw fixation to secure a perfect anatomical result, but external splinting must also be utilized for a few weeks, on account of the great strain of the weight of the leg on the metal plate.

SHAFT OF FEMUR

Fractures of the femoral shaft are most commonly situated at the junction of the upper and middle thirds, and also about the middle of the bone. They may be transverse and comminuted, and due to direct violence, or of the long spiral or torsion type when resulting from indirect twists. The deformity is fairly constant ; the fragments angulate convexly outwards, as viewed from the front, the limb below the break being adducted ; in the higher fractures the upper fragment is also displaced anteriorly, or flexed, and the limb below internally rotated. The amount of shortening varies, being usually about 1 or 2 in., and is due to the original fracturing force, and to the shortening of the longitudinal fascial and muscle ' ties ' from distension by hæmorrhage and inflammatory exudate. In torsion or spiral fractures the displacement may be lateral rather than in the direction of shortening and angulation. The treatment now universally adopted is fixation, traction, and suspension. The most useful appliance is the Thomas bed-splint, with an additional leg-piece hinged to the bed-splint at the level of the patient's knee-joint ; this additional portion, which is furnished with a right-angled foot support, permits early movements of the knee. The bed-splint is suspended from the Balkan frame, by counterpoises, at an angle of about 30° with the horizontal plane. The additional movable leg portion of the appliance, which holds the limb from the knee downwards, is suspended from the bed-splint above, and is slung horizontally. The patient's hip and knee are thus kept flexed, the limb being supported in the splint by a series of flannel slings. A strapping stirrup, applied below the knee, permits a fixed traction on the lower half of the limb, and is fastened by cord to the end of the movable part of the splint ; a second stirrup, applied to the thigh below the fracture, exerts traction along the line of the thigh by means of weights acting over a pulley at the raised end of the main bed-splint. The whole splint thus forms part of the traction system, and the arrangement not only permits passive movements of the knee-joint from the first, but allows a direct and vigorous pull on the lower femoral fragment, a more distributed and gentle pull on the suspended leg, and prevents the splint from slipping downwards off the limb. The amount of flexion of the hip and knee can be varied within wide limits, both to regulate the alinement of the lower femoral fragment and to alter the amount of the traction force. It will usually be necessary

to abduct the limb below the fracture, in order to bring the lower piece of the femur into line with the upper, and this can be provided for in the suspension from the overhead wooden framework. The flannel slings, or adjustable screw pads attached to the splint, can be made to exert a further local control of the fragments, either in antero-posterior or lateral directions. The suspension and traction method is usually very successful in correcting the shortening and the alinement. Great care should be taken to correct persistent outward bowing and any tendency to backward angulation. It is in the first two or three weeks that traction has its most beneficial effect, and during this period particularly the progress of the case must be gauged by radiographing the patient in bed. When the fracture is so low that a stirrup above the knee is impracticable, it may be necessary in place of this to use the Pearson extension calliper; but, without the latter, traction can, to some extent, be exerted below the knee. Very oblique or spiral fractures may present great difficulty in bringing the fragments into apposition, and it may be desirable to cut down and fix them with a Lane plate; or, again, complete lateral displacement or extensive comminution may necessitate the same procedure. Access is best through a long external incision, the vastus externus being reflected forwards rather than split. The metal plate should be long and stout. After plating, until consolidation is complete, the limb should be splinted by some method that will allow early passive movements of the knee. Whether mechanical or operative treatment be the method of choice, the patient will not be allowed to stand much before the lapse of three months, and, as a general rule, a calliper splint should be worn for the first three months, at least, after the patient commences to get up. The calliper splint prevents weight being transmitted through the injured bone. Physio-therapy must be continued until movements of the joints, especially the knee, are complete, and the muscular power practically normal.

LOWER END OF FEMUR

Fractures of the lower end of the femur in the immediate vicinity of the knee-joint have a special significance in their possible effect on the ultimate function of the joint. Those of the lower end of the shaft which do not involve the joint resemble fractures of the mid-shaft, and may be treated similarly; traction above the knee is, however, difficult to apply, and the use of an extended knee position, with traction below the knee, is liable to lead to the persistence of the usual backward displacement of the lower fragment, with the eventual production of apparent hyperextension of the knee-joint when the patient again walks. Fractures of the lower end of the femur are usually more or less transverse, but there is a considerable tendency to comminution, and to the formation of a T-

shaped fracture into the joint, with displacement of one or other condyle ; or long spiked fragments may project downwards into the joint. Fractures into the joint sometimes occur as the result of a fall consequent upon weakness of the limb due to old arthritis of the knee-joint, thus increasing the difficulty in diagnosis and treatment. A not infrequent fracture is that occurring transversely just at the base of the condyles, which slip backwards and give rise to a condition superficially resembling a flexion deformity of the joint ; similarly, comminuted or incomplete fractures may cause a varus or valgus position of the knee. The first essential in treatment is the restoration, in both the antero-posterior and lateral planes, of the normal bearing of the articular surfaces ; second in importance is immobilization of the fragments, with passive movements of the patella from the first, and active and passive movements of the general articulation as early as is safe. Provision must be made also for massage of the thigh, and for graduated faradization of the quadriceps. Traction on a splint hinged at the knee will be used if the lower fragment or condyles can thereby be kept in correct position. Mere clinical observation of the correction is insufficient ; the result must be controlled by skiagraphy. A detached condyle is liable to be displaced upwards for half an inch or more, or the whole lower fragment may be pulled backwards by the gastrocnemius, giving a real but not an apparent flexion of the joint ; in the latter event the knee will need to be flexed to restore the femoral alinement. Where mechanical measures prove insufficient for correct reposition, there should be no hesitation in cutting down and transfixing the fragments with long screws or autogenous bone pegs ; a small transverse lateral graft is a valuable means for restoring loss of bony substance, such as may occur from crushing, and will maintain the level of the condyle. Consolidation proceeds rapidly. Every effort must be made to prevent adherence of the patella, but early movements must not rock the fragments. In the ambulatory stage, a calliper or a ' knee-cage ' will be worn, according as it is more important to relieve the weight-bearing, in the endeavour to prevent the occurrence of knock-knee or bow-leg, or to allow the joint some limited movement.

PATELLA

The patella is fractured either transversely from unguarded movement, or comminuted by direct blows ; in the latter the separation is inconsiderable, while in the former it varies with the extent of the coincident tear of the lateral aponeuroses. A fracture may be quite transverse, or transverse coronally and oblique sagitally. The lower fragment is often small. Open operation and suture, through an incision not over the line of fracture, is now universally practised. Wiring is the usual procedure, but a mattress or circular suture of several strands of fishing-gut

is a highly satisfactory means of fixation. Active and passive movements, within a range of 15°, may be started as soon as they can be comfortably borne, and also massage and lateral passive movements to the patella when the wound permits. The patient may be allowed up, with the knee in a splint, after four weeks ; and a knee-cage, at first considerably restricting movement, but later permitting greater freedom, should be used for another three months. Passive movements other than the gentlest must be avoided throughout ; and care must be given to the re-development of the quadriceps.

UPPER END OF TIBIA AND FIBULA

Fractures of the head of the tibia are not common, but are important in that they almost always involve the knee-joint. As the result of indirect violence, the inner tuberosity of the head of the tibia may be separated along a line which passes from the tibial spine downwards and inwards. The tuberosity is depressed, being broken off cleanly, or crushed and impacted into the shaft below. If left thus, the normal horizontal plane of the tibial articular surface is seriously deranged, and bow-leg deformity and considerable joint disability occur when the patient again assumes weight-bearing. The displacement must be met by open operation, and the tuberosity restored to its correct position and fixed by pegs or long screws. If there is loss of substance by impaction, the tuberosity must be disimpacted with a broad chisel, prised up into position, and the gap filled by a small piece excised from the tibial shaft. Direct violence below the knee is liable to cause a transverse fracture of the tibia just where the head of the bone joins the shaft ; frequently the fracture is badly comminuted, and the head split up into two or more fragments by lines of cleavage passing into the knee-joint. The neck of the fibula is usually also broken. The common deformity in this high fracture of the tibia is adduction, and forward projection of the distal portion of the leg, and, if uncorrected, gives rise to bowed leg and apparent hyper-extension of the knee-joint. Rarely, the upper end of the fibula only is broken by direct violence, the tibia being intact. Transverse fractures of the tibia frequently exhibit no shortening, in which case splintage without extension will be sufficient. Initial deformity should be corrected under an anæsthetic, care being taken to carry the limb distal to the fracture backwards and outwards until the normal contour of the tibia, as compared with the opposite sound leg, is restored. The splint used should allow the knee-joint to be kept a little flexed, and can be of the Mackintyre type, a Thomas knee bed-splint, or of plaster of Paris ; a foot-piece will be provided, but in this fracture, as indeed in all fractures of the tibial shaft, care must be taken not to dorsiflex the foot so much that the lower tibial fragment is forced forwards. Where traction is necessary, it will

be preferable to use a suspended Thomas bed-splint, which can be well flexed at the knee ; stirrup and weight traction can be applied below, and the counter-traction will be exerted by the flannel slings supporting the thigh.

SHAFT AND LOWER END OF TIBIA AND FIBULA

In a discussion of fractures of the shafts of the tibia and fibula it is advisable to consider at the same time those of the lower end, some of which involve the ankle-joint. Fractures of the shaft fall into one or other of two groups : the transverse, due to direct injury ; and the spiral or ' torsion ' fractures, which result from twists applied to the foot. Direct violence may produce a simple transverse break in the tibia, with fracture of the fibula about the same level, but more frequently comminution of the tibia occurs, often of considerable degree. As a rule there is much displacement, the lower fragments lying behind and to the outer side of the upper, and shortening exists to the extent of one-half to two inches. Angular deformity, convex backwards, may also be present, but this is more liable to be brought about by efforts to keep the foot up at a right angle, in the first attempt to correct the deformity, than by the original fracturing force. The indirect, spiral, or ' torsion ' fractures should be studied together with those occurring in the neighbourhood of the ankle-joint, which, according to the severity of the deformity, are commonly known as the various degrees of Pott's, and Dupuytren's, fractures. The mechanism of production of oblique fractures of the shaft of the tibia is the same as that of Pott's fracture, and the type of deformity produced is similar ; the differences are merely in the position or height of the oblique plane of fracture as it cuts the leg bones, and in the severity of the resulting deformity. The principal mal-effect of each, whether the infraction plane lies in the shaft or passes through the malleoli, is the same, namely, the disturbance of the horizontal axis of movement of the ankle-joint, and of the horizontal upper bearing surface of the astragalus. In the trans-malleolar fracture the disability is liable to be more serious, as in this case the oblique plane of infraction passes through the ankle-joint itself, and, in addition to the derangement of the horizontal axis of motion, the grip of the malleolar mortise on the sides of the astragalus is disturbed, and made irregular and loose ; thus, in addition to restricted movement from an improper weight-bearing position, there is restriction from relative alteration of the articular surface and from bony locking, well illustrating the fact that the disability resulting from a fracture is directly proportional to the proximity of the fracture to the joint. All indirect fractures of the leg about the ankle, and of the shaft of the tibia and fibula, are due to a twist of the foot ; in the majority the foot is thrust outwards (abducted or ' valgus ') and backwards, the foot usually

being held by the ground while the leg and trunk above rotate in the opposite direction ; in the remainder the foot is twisted inwards (adducted or 'varus'). In forced abduction injury the simplest effect may be not a fracture, but only a sprain of the internal lateral ligament of the ankle-joint ; more important, however, is the occurrence sometimes of impaction of the outer articular facet of the body of the astragalus on the anterior border of the external malleolus, causing a very local bruising of the articular cartilage at this site, which may give swelling, pain, and local tenderness lasting for months. Operative exploration shows a tiny granulating patch on the opposed articular margins. Next in order of severity is the 'first degree' of 'abduction fracture', where the external malleolus is twisted off, but not displaced, and the internal lateral ligament of the ankle-joint ruptured ; the fracture in the fibula is from one to one and a half inches above the tip of the external malleolus, and is oblique from below upwards and backwards. In this degree, instead of the internal lateral ligament tearing, the internal malleolus may be snapped across at its base, but without displacement. In the 'second degree' of abduction fracture both malleoli are broken as described above, but are also displaced, and the position of the foot is altered relative to the axis of the leg. The external malleolus goes backwards and outwards, rotates outwards, and slides up a little on the upper fragment, being thus shortened from one-quarter to three-quarters of an inch. The astragalus subluxates outwards, going with the external malleolus, and rotates on its antero-posterior axis ; its upper surface no longer articulates parallel and horizontal with the lower end of the tibia, but the outer edge of its upper surface is jammed into the crevice of the lower tibio-fibular junction—a most improper and unmechanical arrangement for weight-bearing, as the direct line of body-weight is now transmitted through a crevice to an edge of the astragalus instead of through two opposed flat articular surfaces. Also the internal malleolus is displaced outwards, becoming oblique instead of vertical, as the tip goes farther out than the base, and is separated from its corresponding lateral astragaloid facet by an interval of about one-third of an inch. The 'third degree' of abduction fracture at the ankle is characterized by deformity so great that the astragalus is completely dislocated backwards from the lower end of the tibia ; in other words, there is a complete backward fracture-dislocation of the ankle-joint. The malleoli are fractured as in the second degree, but with more displacement backwards ; the external malleolus is also rotated on its plane of fracture. In addition to the purely malleolar fractures, a large fragment is separated and displaced backwards from the outer and posterior corner, or from the posterior edge, of the lower end of the tibia, being carried backwards with the foot as are the malleoli. Sometimes in this third degree of abduction fracture the

foot appears to be wedged up between the separated malleoli, and to this the name 'Dupuytren's fracture' has been applied. The classification of fractures about the ankle-joint here adopted is that of Sir Arbuthnot Lane, and it would be wiser, with him, to call them degrees of 'abduction' or 'adduction' fracture, an etiological nomenclature, rather than retain such terms as 'Pott's' and 'Dupuytren's fractures'. While in some cases abduction torsion of the foot produces the various ankle-joint fractures described above, in other cases similar violence may cause fractures higher up in the shafts of the tibia and fibula, which resemble the ankle-joint fractures in their oblique plane of infraction, and in their production of abduction and backward displacement of the foot. Not only is the plane of infraction, as it crosses the two bones, oblique, the fibula always dividing at a higher level than the tibia, but so also is the plane of cleavage in the tibia itself. The break may be anywhere in the lower two-thirds of the tibia, and at a correspondingly higher point in the fibula. Besides the displacement of the foot outwards and backwards, the lower fragments are external and posterior to, and are overlapped by, the upper. Instances of this type of fracture of the shaft may show very different degrees of severity. Sometimes there is only an incomplete L-shaped infraction of the lower tibia, the tibia being merely 'sprung', with perhaps some abduction displacement of the lower end of the tibia and foot; in other cases the tibia is completely divided but the fibula is intact. Whether the tibia is merely obliquely divided or shows a typical long spiral cleavage will depend on whether the fracturing force was merely one of abduction, or abduction associated with severe external rotation of the foot. The external malleolus is the buttress preventing undue abduction of the foot, but the resiliency of the fibular shaft is an efficient safeguard against fracture except in severe violence. The 'adduction' fractures in the vicinity of the ankle-joint are not nearly so common as the abduction fractures described above, nor have they their counterpart in similar fractures of the shaft. They are due to a fracturing force which produces severe adduction, supination, or 'varus' strain of the foot. Two degrees have been described, the first with no deformity, and the second with a varus displacement of the foot at the ankle-joint. The fracture of the malleoli is the same in each; the external malleolus shows a not very oblique infraction where it is snapped over the lower end of the tibia, and there is also a short oblique fracture of the internal malleolus at its base, due to the strong push inwards sustained from the astragalus. The deformity in the second degree may be very considerable. A rare but important fracture occurring in the juxta-epiphyseal region of the lower end of the tibia in children is that which results in destruction of the epiphyseal cartilage. It causes a loss of growth of the lower end of the tibia, while that of the fibual

continues. The external malleolus becomes too long, and both malleoli turn inwards, and the foot becomes increasingly deformed in the varus position. The condition is met by postponing correction as late as possible, and then removing a piece of the fibula at the base of its malleolus, and transferring it as a graft to fill the gap produced by correcting the foot after doing a linear osteotomy of the lower end of the tibia as near the ankle-joint as possible.

The great mechanical desideratum in the treatment of fractures of the shaft of the tibia and fibula, and in those of the lower end, as well as in operative procedures for the correction of mal-union, is to restore the horizontal axis of rotation of the ankle-joint, and to restore and retain the horizontal and parallel flat-bearing surfaces of the normally apposed tibia and astragalus. Anything short of this is failure. If this ideal is attained, it will follow in most cases that the second condition is also met, namely, that the normal line of strain through the knee-joint, and the level of its bearing surfaces, are restored. When, as may occur in transverse fractures, no overlapping of fragments is present, and thus no shortening, but only angular deformity, traction will not be required, and the leg can be efficiently splinted either in plaster of Paris, cut up and made removable, or in malleable metal 'fracture' splints applied along its posterior and lateral aspects ; the knee-joint and foot will be included. Care must be taken to avoid a backward bowing at the seat of fracture, and therefore the foot should not be too dorsiflexed ; again, the normal bowed shape of the tibia must be remembered, and the production of an abducted or valgus foot prevented by not putting up the tibial fragments in an exact straight line. The reduction must be carefully controlled by skiagraphic examination, and for this reason plaster is to be preferred to metal splints. Padded wooden splints are clumsy, useless, and ought to be obsolete. The use of massage and gentle movements will depend, as to the time of their utilization, on the stability of the reduction and the proficiency of the masseuse ; the earlier they are begun, of course, the better. If care is taken to retain one side of the limb in the half splint while the other is being massaged, this treatment may begin almost on the second day. When the fragments overlap and shortening exists, either traction or reduction by open operation becomes necessary. The application of traction in fractures of the middle and lower part of the leg is a practical difficulty, on account of the shortness of the segment of the limb below the fracture. The strapping stirrup has been at times substituted by transfixion pins, ankle spats, gauze glued to the sole, &c., but all are equally unsatisfactory. It is, therefore, in fractures of the leg that reposition of the fragments by open operation, with or without internal fixation, is especially called for, and of the greatest service. In transverse fractures it is often sufficient to correct the over-

lapping and appose the broken ends by the process of first 'angulating' the fragments; considerable overlap may thus be corrected, and it is very seldom necessary to sacrifice length to procure alinement. The reposition may then be found to be so secure that the external application of plaster of Paris will be enough. In oblique and spiral fractures the correction of the length and alinement may be much more difficult; and, further, when the deformity is thus corrected, the position is so unstable that a metal plate or bone graft must be applied to maintain the correction. By a combination of traction on the foot, rotatory and sliding manipulation of the fragments with the large bone-holding forceps, and the use between the fragments of an elevator serrated on its edges, the most oblique overlap can be fully corrected. When the strain on the reduced fracture is great, it will be necessary to use an 'eight-' or 'ten-hole' metal plate, which must be applied on the external surface of the tibia, and bent to follow the normal contour of that part of the bone to which it is applied. The plate is buried so as to be well covered by muscle, and the skin incision so planned that it is as far from the plate as possible. The plate can be applied to hold comminuted fragments in position, or smaller subsidiary plates can be used. Metal on the subcutaneous surface will sooner or later require removal, but on the external surface it should remain permanently if rigid fixation and asepsis are ensured. As an alternative to the metal plate in cases where there is no great strain, the fixation may be accomplished by sliding a graft, of half an inch width, cut from the subcutaneous surface of the longer fragment, into a groove in the other fragment; if possible the graft should be at least four inches in length and one-half of it should lie on either side of the line of fracture. If the sides of the graft be cut not quite parallel, it will act as a wedge and fix itself when slid, and no internal sutures will be necessary; the piece cut from the lesser fragment can be put into the cavity left in the greater. Subsequently, as after plating, external splinting will be required for about six weeks.

In the treatment of fractures of the leg which involve the ankle-joint, it is, without doubt, of the first importance to reduce the deformity completely, however little may originally exist. The difference of opinion that exists on the question of the adoption of open operation, or mere manipulation, in the treatment of the severer abduction fractures has its origin in the belief of the advocate of either measure in the success of his own method to procure absolute anatomical reposition. As Lane has pointed out, the external malleolus is the important buttress preventing lateral abduction at the ankle-joint, and if the length, alinement, and rotation of the malleolus be restored, the astragalus must fall into perfect relationship with the tibia. To attain this, if there be any residual deformity whatever after manipulative correction, he fixes the fibular

fragments by a small narrow plate applied to the posterior surface of the fibula through an incision rather to the front of the bone. When no original deformity exists, or where this has certainly been completely corrected under an anæsthetic, no operation is required, and it is sufficient to use the simplest splints, such as metal fracture splints and a 'club-foot shoe', or the more retentive plaster of Paris, according to the tendency to recurrence of the mal-position; in the latter case the plaster can be cut up after a few days, and in both early massage may be begun. In the manipulative correction, traction is put on the foot while counter-traction is applied to the leg above; lateral pressure is made on the foot in an inward direction, and a 'varus' or supination position is attempted at the ankle-joint itself; at the same time, while the above strains are being applied, the heel is thrust well forward and the front of the ankle backwards, and the foot is inwardly rotated at the ankle-joint. When all this has been attained, the foot and leg are securely fixed in splints in this combined position. The result must be controlled by skiagraphic examination, which, if the reduction has been successful, should show a correct position of the external malleolus, and the normal parallelism of the articular surfaces of the astragalus and tibia; the outer edge of the upper surface of the astragalus must not be left impacted against the tibio-fibular articulation. The greatest difficulty in the manipulation is the restoration of the length of the fibula. In the ambulatory stage, which should not be before six to eight weeks, the patient should be given an outside steel to the knee, a crooked or wedged heel on the inner side, and an inside **T**-strap, and the appliance should be worn from three to six months. If he be allowed to walk with ever so little residual abduction deformity, it is practically certain that in time pain, swelling, weakness, and stiffness of the ankle-joint will ensue—the symptoms of uneven bearing and of mechanical arthritis; and instead of the normal leverage function, the toe and heel action at the ankle-joint, he will substitute the dead, immobile, everted, heel, or 'pedestal' gait. The usual operative procedures for mal-united abduction fractures do not give the amount of relief generally imagined. Although they may relieve the disability to a certain extent, and still more the anatomical appearance of the foot and ankle, yet their effect in improving the ankle-joint function is very small. The commonly adopted measure of trans- or juxta-malleolar osteotomy does very little to restore the correct relationship of the astragalus to the tibia. The ideal method is that of osteotomy of the fibula and internal malleolus, with such stretching and correction of the peroneal soft parts as will permit the permanent lengthening of the fibula by the insertion of a bone graft; the mechanical difficulties of such an operation are great. Adduction fractures about the ankle-joint do not usually present any great difficulty in manipulative reduction, and the

subsequent treatment is along the above lines. Open operation will rarely be necessary, but if called for, small metal plates on the malleoli will enable perfect apposition to be attained ; plates on the internal malleolus will require removal subsequently.

ASTRAGALUS

Fracture of this bone is due to force exerted on the foot, and has of late frequently been met with bilaterally in those sustaining injuries from aeroplane ' crashes '. The fracture is usually transverse from side to side, and much more often through the body of the bone than through the neck. The posterior portion may be displaced behind the ankle-joint, or the anterior to the front, or both fragments may be displaced. There may be some comminution, but more often there appear to be only two fragments. The fracture is serious in that it involves the two chief joints of the foot. The damage to the ankle-joint is liable to lead to some, or complete, loss of extension and flexion of the foot ; and the involvement of the subastragaloid joint almost invariably causes absolute impairment of the adduction and abduction action of the foot, a movement quite as important as the flexion and extension range at the ankle. If there be any displacement whatever, the treatment will be by open operation, with the object of replacing the fragments ; those pieces which cannot be restored must be removed, especially if in such position as will later cause impairment of motion by bony locking. Total astragalectomy is a very much over-rated operation, and its functional results disappointing, even though, as Whitman insists, the foot at the operation be thrust well backwards on the leg ; it can, perhaps, give no worse functional result than leaving a permanently crushed astragalus. Access to the astragalus may be through anterior, posterior, or external lateral incisions, according to necessity. When no displacement exists, a rare contingency, early massage and active movements may be adopted, but weight-bearing should be prevented for at least three months.

OS CALCIS

The os calcis is fractured as the result of falls from a height upon the heel, and, as in the case of the astragalus, the condition is often bilateral. The injury is of a ' crush ' nature, with broadening of the bone from side to side, and diminution of its depth. Skiagraphy may reveal only the appearances of a crush, or a main line of fracture running from above and behind downwards and forwards ; sometimes the greater process is separated. Fracture of this bone is almost invariably very disabling, in that the complicated sub-astragaloid joint is deranged, with consequent impairment or absolute loss of adduction and abduction (supination and

pronation) action of the foot ; also, the long-continued inability to walk any distance, and the constant pain as the result of the attempt, are notorious. The treatment is wholly conservative, operative measures having no field. Long-continued rest off the foot, with the early application of all forms of physio-therapy, are all that can be done in the early months. Later, when the patient must walk, an appliance consisting of a boot with inside crooked heel, outside steel, and varus strap, as described above for abduction fractures of the ankle, together with a rubber pad under the heel and a sole plate, both of which relieve local pressure, will materially assist him in getting about. If projections and spurs give trouble, they may be chiselled off. Attempts to obliterate the sub-astragaloid joint absolutely, by the operation of 'arthrodesis', with the object of relieving pain in old-standing cases, do not appear to give as much relief as does the use of the walking appliance mentioned above.

FORE-FOOT

Any of the bones of the foot in front of the transverse medio-tarsal joint may at times be fractured as the result of direct injury, but some are more liable than others. The *scaphoid* may be crushed in its body, with extrusion of some of its fragments, or the tuberosity may be broken off. At times the whole bone, partially crushed, is almost completely dislocated to the dorsum or inner side of the foot. On the whole, replacement is not very satisfactory, even if it can be accomplished, and it is better to excise the whole bone ; otherwise an everted position of the fore-foot is permanently assumed. After operation the fore-foot is adducted, and the foot and leg fixed thus in plaster for four to six weeks, and subsequently weight-bearing is permitted in the walking appliance described above for abduction fractures of the ankle, together with a well supporting arch plate in the boot. The functional result is good. The *cuboid* and the *cuneiform bones* may be crushed or split, but the displacement is usually inconsiderable, and excision never necessary. The late results on function are the production of occasional pain and weakness, and of some stiffness. Jagged fragments which cause irritation from pressure of the boot may be removed. The commonest simple *metatarsal* fracture is that of the tubercle on the outer side of the base of the fifth, and may occur from twisting the foot ; displacement is unusual, and no disability results providing weight-bearing is not allowed for three or four weeks. Fracture of the bases of two or more contiguous metatarsals can occur as the result of a sudden wrench. An interesting fracture is that of the middle of the shaft of the second or third metatarsal bone, which may be due to a trivial accident to the foot in ordinary walking, as, for example, in soldiers on the march. No displacement occurs, and the patient may be unaware of its existence ; a little pain

and tenderness, and puffiness on the dorsum of the foot, are all the symptoms, and an unsuspected fracture is revealed by the routine skiagraphic examination. A violent direct injury may break the first metatarsal either at its base or just behind the head of the bone. The *sesamoid bones* of the great toe are at times broken, giving rise to pain which may persist for months. In such cases removal is indicated, and it sometimes happens that another sesamoid forms at the site of that removed. Fractures of the *phalanges* occur as the result of things dropped upon the toes. The most important point about them is to take them seriously, and not allow the patient to get about at all for two or three weeks, and until union is complete ; otherwise a chronically swollen and painful toe will persist for weeks, and be a veritable nuisance. In a general way this applies to a fracture of any of the small bones of the foot. Consolidation takes the same time, whether the bone be big or little, and early movement, especially in the severe weight-bearing function of the foot, will lead, in incomplete union, to increase of callus formation, pain, stiffness, and swelling. A minor fracture may give a major disability.

SPLINTING OF WAR FRACTURES

I. SPLINTING FOR TRANSPORT.

II. SPLINTING OF FRACTURES OF THE FEMUR AT BASE HOSPITALS.

BY

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SPLINTING OF WAR FRACTURES

Scope of Chapter. In the following pages it is proposed to indicate very briefly the guiding principles that should be followed with regard to the splinting of various classes of fracture from the first possible moment after the injury has occurred, with particular reference to the methods that may be adopted in order to reduce as far as possible the amount of deformity that is liable to occur in so many of the more severe war injuries. It must be borne in mind that every case of fracture passes through three chief stages, in each of which the principles of splinting are the same but details will vary according to circumstances. The three stages are as follows:

I. In the line and from it to the C.C.S. Here every effort is concentrated on rapid evacuation, combined with arrest of hæmorrhage and efficient fixation of any injured bone. Cases of fracture usually require at this stage most active treatment for the prevention of shock, particularly fractures of the femur.

II. At the C.C.S. At the C.C.S. there is more time and opportunity to care for the patient than in the previous stage, and it is here that most can be done by the surgeon to limit sepsis, prevent gas gangrene, deal with the injuries to bone and soft parts, and remove foreign bodies. The guiding surgical principles at this stage are to remove as little injured bone as possible, to combat the sepsis by efficient drainage and the wide excision of damaged tissue (as introduced by Colonel Gray), and to initiate any special treatment that may be indicated, e.g. B.I.P.P. and Carrel. These surgical details are dealt with in another chapter (pp. 27–37).

III. At the Base and home hospitals. The main treatment of the injury is undertaken here, and all definitely reconstructive surgery is necessarily performed at this stage; but it is during the preceding stages that so much can be done to minimize the amount of deformity that may ultimately require correction; and this object is in the main achieved by the application from the earliest possible moment after the receipt of injury of efficient methods of splinting. It is proposed to consider here some of the forms of splinting that are particularly suitable for application at each of the three stages outlined above.

General Principles governing Splinting. The principles that guide all splinting at every stage are :

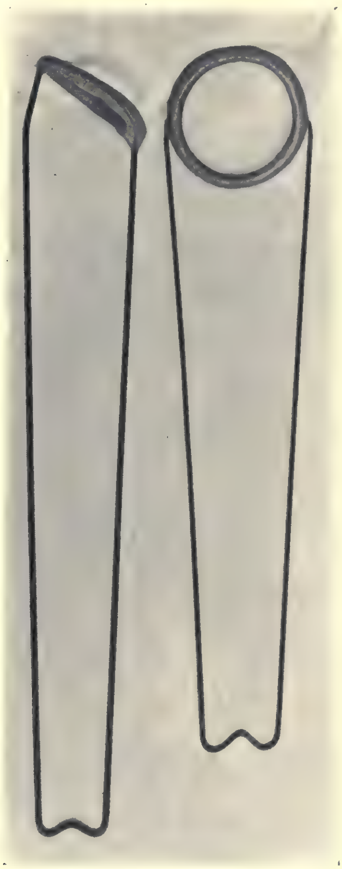
1. Replacement of fragments into their former anatomical position.
2. Prevention of the excursion of the fractured ends into undamaged tissue.
3. Immobilization of the joint above and below the site of fracture so that there shall be no muscle movement across the injured area.
4. Fixation of the limb in such a position that should ankylosis of a joint occur it will be in the 'posture of election'—that is, the position in which, in spite of deformity, the limb will be of most use to the patient.
5. Anticipation and prevention of deformities following scar contraction during healing.
6. Avoidance of compression of an injured limb above the site of fracture.
7. Provision of easy access to all dressings of wounds.

These principles allow of only one method of holding a fractured bone, and that is by extension ; and a splint used in any of the three stages must depend upon adequate extension for its efficiency. It is beyond the scope of this chapter to enumerate the many excellent splints which are being used for fractures during the first two stages, therefore a single method of splinting which combines many advantages with very few disadvantages has been selected for description in full detail as a standard type of treatment.

I. SPLINTING FOR TRANSPORT. (I) SPLINTING OF FRACTURES IN THE LINE

Type of Splints required. It will at once be recognized that in any injury caused either directly by a missile or indirectly by the crushing force of an explosion, the amount of damage to bone and to the soft tissues is often much less immediately after the injury occurs than when the patient arrives at a hospital. It requires a very small effort of the imagination to picture the aggravation of the injury that takes place, for instance, round the sharp splintered ends of a badly comminuted femur when the case is being dragged across the open or carried to the regimental aid post. In order to minimize such aggravation of injury, it is of the utmost importance that some form of splinting should be adopted which will secure efficient fixation of the fracture as soon as possible after the receipt of injury, and if possible before the journey to the regimental aid post is begun. The splinting at this stage will naturally be temporary, because the splint must be applied before the wound is investigated, and attention must be concentrated solely upon securing immediate and efficient fixation. A splint therefore at this

stage must be (1) simple, (2) easily applied, and (3) easily carried. The splints which appear to meet these requirements most satisfactorily are the Thomas splints for the arm and for the leg. As experience has shown



2. 1.

FIG. 10.

1. Swivelled Thomas arm splint, showing the side bars pivoted direct to the ring
2. Thomas leg splint. With a small ring suitable for later stages in the treatment of fractures of the lower limb.

that the Thomas splints are capable of such wide application, it is proposed to select them and the method of their application for description.

Thomas Arm and Leg Splints. The 'swivelled Thomas arm splint'. This splint consists of a ring 7 in. in diameter which is padded and covered with soft leather, and side bars of $\frac{5}{16}$ in. iron which are pivoted direct to this ring or hinged 1 in. from it. The side bars end in a notch or **V** over which extensions are tied (Fig. 10).

The 'Thomas leg splint'. This consists of an oval ring set obliquely to two side bars. The ring varies in size from 16 in. to 30 in. in circumference and is carefully and firmly padded with leather. The side bars are of $\frac{3}{8}$ in. round iron and end in a notch or **V** at the foot end. Various additions, such as foot suspension pieces, splint props, &c., are fitted to the Thomas splint when indicated. (Figs. 10 and 11.)

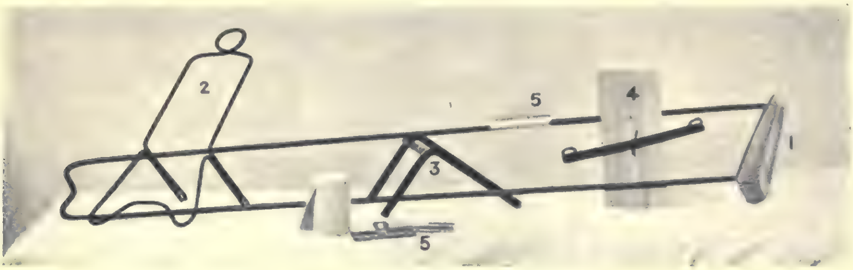


FIG. 11.

1. Small ringed Thomas leg splint.
2. Suspension foot-piece.
3. Splint prop, fixed to the end of the splint and used for fixing the leg extensions below the level of the side bars of the splint.
4. Serrated wooden foot-piece.
5. 4 in. paper clips for holding supporting bands.

Splinting of different Classes of Fracture.

A. The Upper Limb.

1. In all cases of injury to the **scapula, clavicle, and the head of the humerus**, no splint is required from the line to the C.C.S. and from the C.C.S. to the Base: efficient fixation of the arm on the injured side should be secured by means of a firmly applied bandage. The associated lesion of lung, vessel, nerve, or muscle is the more important injury, and with the arm bound to the side no further damage can be done by the injured bone.

2. In fractures of the **shaft of the humerus**, in all injuries round the **elbow-joint**, and in fractures of the **bones of the forearm,** a swivelled Thomas arm splint gives as good results as any other, and is extremely efficient in immobilizing the fracture. It depends upon extension alone to keep the fractured ends from ploughing up the soft tissues, and does not cause any circular compression of the limb. The mode of application is as follows:

The arm is held away from the body, the splint is then slipped over it with the bars opposite the coracoid process and the spine of scapula respectively; a carefully padded bandage extension is put

round the wrist and fixed over the **V** in the end of the splint. Too great extension must be carefully avoided ; all that is required at this stage is sufficient extension to keep the bones immobile and the splint in position, and effort should be directed to securing these ends and not too much towards overcoming shortening. The extension having been applied, a bandage is run round the arm, dressing, and splint. The swivelled ring of the splint allows it to be brought down to the man's side without increasing the extension or compressing the axilla. A patient can walk with this splint, and when a stretcher or ambulance is available he can lie down with his arm to his side in comfort. On the stretcher the splint should be suspended from a stretcher suspension bar.

B. The Lower Limb.

1. In fractures of the lower limb the problems of transport during the first stages are extremely difficult. The Thomas leg splint is by far the most efficient method of dealing with all injuries below the upper third of the femur. Even **fractures of the upper third** and neck of the femur can be controlled by it provided a good extension be obtained from the tuber ischii, but the ring of the splint is very much in the way where there are large buttock or perineal wounds. From the line to a C.C.S. the Thomas leg splint is probably the only splint available for all fractures of the femur ; but if wounds are very severe and the fracture very high, the limb and trunk may be secured directly to the stretcher by the fixation of a perineal band to the head of the stretcher and traction of the leg to the foot of the stretcher by means of a padded bandage.

2. In all fractures of the **lower two-thirds of the femur, injuries of the knee-joint, and fractures of the tibia and fibula,** the Thomas leg splint should be applied at the earliest possible moment. From the line to the C.C.S. it should be put over the clothing, after the wound has received the first-aid dressing and hæmorrhage has been dealt with. Extension must be obtained by some method that is extremely simple, because the splint has to be put on under appalling difficulties and usually by partly trained bearers. There are several rapid ways of getting extension. One method is by means of a crossbar through the boot, the uppers being cut on either side just below the instep to allow a metal or wooden rod to be passed between the foot and the sole of the boot ; this rod rides on the side bars of the splint and efficient traction can be made from it (Figs. 12 and 13). Another method is by means of Tapson's sole-clip, which grips the sole of the man's boot. Yet another method is that of taking a pull from the heel and dorsum of the boot by means of a webbing brace. After extension is applied a long gutter splint of gooch should be used as a ham splint, and slung from the sidebars of the Thomas, and the whole limb bandaged into the splint. (Fig. 13.)

3. Fractures of the **ankle and tarsus** can be efficiently immobilized at this stage by means of a posterior splint and foot-piece.

FIG. 12.—A method of obtaining temporary extension by means of an iron bar passed through the boot below the sole of the foot.

FIG. 13.—A Thomas splint as applied in the line and slung from a stretcher suspension bar.

(II) SPLINTING AT THE C.C.S. FOR TRANSPORT

At the C.C.S. the real work of the prevention of future deformity is taken in hand. The saving of life and limb is the primary consideration, and that can be done best by bringing the bones into as nearly anatomical reposition as possible. The purely surgical side of the treatment is dealt with elsewhere in this book, and attention is directed here solely towards the splinting.

After the surgical toilet of the wound and the general cleansing of the limb has been completed, the Thomas splints described above may be applied in a more permanent manner to ensure the patient's travelling in comfort, and to give perfect access to dressings.

The Glue and Gauze Method of Extension. A permanent method of applying extensions is necessary for all fractures and can be obtained by the use of zinc oxide strapping or adhesive plaster; but the best and most efficient method is by means of a new adhesive now known as Sinclair's glue. The details of its preparation and mode of application are as follows:

(*a*) **Preparation of Glue.** The glue is made according to the following formula:

Very good glue	50 parts[1]
Water	50 ,, [2]
Glycerine or glucose or calcium chloride . .	4 or 6 parts[3]
Menthol	1 part

Stand for 12 hours, then melt on a water bath. Neutralize to litmus with sodium hydrate, because commercial glue contains at times free hydrochloric acid. The whole preparation should be made sterile.[4]

(*b*) **Application of Glue and Gauze.** The gauze extension should be applied as follows:

(1) Do not shave the skin.

(2) Wash the skin carefully with soap and hot water which contains about 4 drams of washing soda to the pint, to convert the oil of the skin into soap. Glue will not adhere to a greasy surface.

(3) Dry the skin.

(4) Apply the warm glue evenly by means of a shaving brush or the

[1] Only very good glue should be used, and it may be tested as follows:
Place 4 oz. of glue in 4 lb. of cold water and leave in a cool place for 12 hours. If after this period it is completely dissolved, the glue is bad.
If it forms a mass coherent and gelatinous, weighing 8 oz., the glue is good.
,, ,, ,, ,, 16 ,, ,, very good.
,, ,, ,, ,, 20 ,, ,, excellent.

[2] Frequent heating evaporates the water, which should be added from time to time. When re-heated many times the adhesive power is lost.

[3] Add 4 parts in summer and 6 parts in winter. The calcium or glycerine is used to prevent the adhesive becoming brittle, and the proportion may be varied in accordance with the sample of glue used. These ingredients allow of a certain amount of transpiration from the skin by their deliquescent qualities, so that there is never any sodden condition of the epithelium underneath when the extension is removed.

[4] The menthol acts as a mild antiseptic.

Note that the adhesive can be made waterproof if necessary by painting with a 2 per cent. solution of potassium bichromate. This must be painted over the extension in the dark and immediately afterwards exposed to the light. Painting with a 10 per cent. solution of formalin also renders glue insoluble. These points are useful when the Carrel treatment is being used for wounds near the extension.

hand, taking care that it is not too hot, and brushing all the hairs of the limb in an **upward** direction.

(5) Take white gauze from a sterile package, folding it so that it is 8 layers in thickness, and cut it to the desired length. Keep a tension on the gauze and bring it quickly but carefully into contact with the limb (inner and outer surfaces); then apply neatly a loose-woven bandage, taking care that there are no folds or creases in the gauze. (In the case of the leg another method is to apply a length of Maw's elastic cotton stockinet; then glue thoroughly and apply the gauze outside it, and bandage as before.)

(6) When dry, apply traction. Ordinarily traction may be applied within a few moments of application; but if a heavy pull is required, as is the case when there is much overlapping of bone, it is better to wait a few hours before the full strain is put on.

The gauze extension must always be applied very carefully, in which case it will be an extremely rare occurrence to have blistering, or indeed any trouble. It is, however, apt to slip when the injured limb atrophies. Whenever this happens an entirely fresh extension should be applied, otherwise the whole pull is along the lines of contact between gauze and skin and a blister occurs which is purely traumatic in origin. Tickling or burning under the extension is the sign of irritation and an indication that the extension must be changed. In cases of fracture of the femur this is usually necessary about the tenth, twentieth, and fortieth days.

Splinting of different Classes of Fracture.

A. The Upper Limb.

1. In fractures of the humerus, in injuries round the elbow, and in fractures of the forearm, the swivelled Thomas arm splint should be applied as follows:

In **fractures of the humerus and in injuries round the elbow** extensions are applied to the radial and ulnar margins of the forearm, so that when the splint is put on, the hand will be in the same plane as the side bars. In **fractures of the forearm** or the **carpus** the extension is taken from the palm and dorsum of the hand by means either of gauze or of a thin cotton glove with extension tapes from the finger tips. When the extension has been applied, the splint is put on with the arm at right angles to the body, and the bars of the splint opposite the coracoid and spine of the scapula respectively. The extension is then tied directly over the end of the splint, and can be adjusted to keep the forearm in full supination. The injured limb is slung to the upper bar by means of flannel bands, passed round the arm and over the upper bar, where they are pinned or clipped; then across the back of the arm to the lower bar, where they

are again pinned or clipped (Figs. 14 and 15). Care must be taken to sling the elbow well clear of the lower bar so that the internal epicondyle will not bear upon it, and to have the edges of the bands touching so that no zones of œdema will occur. The whole limb now rests upon a gutter made by the flannel bands. When in a ward the splint should be rotated so that the palm of the hand looks directly upward, and the arm should

FIG. 14.—Fracture of lower third humerus: showing (1) glue and gauze extensions applied to forearm; (2) method of slinging arm to upper bar of splint.

FIG. 15.—Same as Fig. 14. Showing arm brought to the side, the position for transport. The centre band is unpinned to show detail of application.

be brought out to an angle from the body either by means of an overhead suspension or by placing the end of the splint on a locker. For travelling the whole limb and splint should be covered by padding and a bandage, and the arm brought down to the side of the patient.

At this stage it requires very little extension to get the ends of a shattered humerus in good position, and dressing the wounds is extremely easy. An assistant holds the arm at right angles to the body; the slings at the site of injury are loosened, the wound cleaned, and fresh dressings and slings applied. The subsequent splinting of these fractures will be

dealt with elsewhere (p. 119). The method just described is designed primarily for transport and to tide the patient over the initial sepsis. It is, however, useful for permanent treatment when slung to an overhead suspension ; but, in this case, immediately the temperature and pulse show that sepsis has been overcome, the elbow must be gradually flexed by some such means as a Sinclair flexion attachment. The elbow must not be kept in full extension for longer than three or four weeks.

2. **Fractures of the metacarpus** are easily fixed by an anterior splint, either of wire or gooch, the splint being padded so that the wrist is in dorsiflexion and the fingers in full extension.

FIG. 16.—Jones's abduction frame, as used for fracture of the upper third of the femur. Showing 'groin strap' on uninjured side and extensions on both limbs.

B. The Lower Limb.

1. **In fractures of the upper third of the femur,** if the case can bear the journey, Jones's abduction frame, with a movable leg-piece, is undoubtedly the best method of transport (Fig. 16). In the application of the frame the most important points are :

(1) That the trunk be not too far down on the saddle. The internatal cleft should be just clear of the edge of the saddle.

(2) That the groin strap be kept tight.

(3) That extension be applied to both limbs.

When in the ambulance or train the injured limb must be adducted in its leg piece so that the patient may be fairly easily handled. (This splint, when provided with an interruption over the wound area, can be used for permanent treatment if a net frame—to be described later—is not available.)

2. All fractures of the shaft of the femur, all injuries to the knee-joint and fractures of the tibia and fibula, bear transportation best in a Thomas splint, which should be applied immediately after the surgical toilet of the limb has been completed. In **fractures of the shaft of the femur** the following technique gives satisfactory results :

A splint is chosen with a ring which just clears the dressings. Too large a ring is a great mistake, not only because it slips across the perineum, pressing upon the urethra and obstructing the anus, but also because it causes an adduction displacement of the lower end of the upper fragment, whenever extension is applied. A 27 in. ring is large enough for the biggest man even when the thigh is much swollen. Most cases are efficiently fixed by a 22 in. ring.

Extensions are applied as detailed above (p. 99). The glue application to the leg should be from a hand's breadth above the malleoli to the knee-joint ; and gauze and glue should also be applied to the sole and dorsum of the foot so that it can be suspended. The splint is bent to an angle of 160° exactly at the level of the knee-joint, and is then slipped over the limb. (The reason for this bending of the splint will be dealt with later, p. 114.) A foot suspension piece is attached to the splint at the level of the sole by means of tapes or 1 in. adhesive.

The first supporting band, consisting of a 4 in. strip of flannel bandage, is applied immediately at the site of fracture and fixed with safety-pins or with a 4 in. paper clip ;[1] and this band, the 'master band', should be tight enough to keep the bones at the level of the side bars of the splint. Full extension is now taken, counter-extension being made with the splint ring against the tuberosity and the ascending ramus of the ischium ; and the gauze, which is passed outside the foot suspension piece, is tied over the **V** at the end of the splint. The foot is slung at right angles by means of the strips of gauze previously applied to the sole and dorsum, which are tied to the top of the suspension piece, the malleoli being kept 1 in. below the level of the side bars. The rest of the flannel supporting bands are then carefully applied so as to form a perfect gutter from the ham to the lower third of the leg. The knee, carefully padded on its lateral aspects, is finally bandaged into the splint (Fig. 17).

The great advantage of this method of splinting is that while the fracture is absolutely fixed, access to the wound is most easy. The dressings can without difficulty be changed anywhere *en route*. It is most

[1] For the fixing of all supporting bands to a Thomas splint 4 in. paper clips are greatly superior to pins (1) because of the great ease with which they can be applied, (2) because by their use absolutely perfect adjustment of the bands to the folds of the limb can be assured, (3) because the risk to the surgeon or staff of septic infection due to pricks from safety-pins is removed.

important to insist that the posterior bands are loosened one at a time when dressings are done. When on a stretcher, the ends of the splint should be slung to two stretcher suspension bars, to give comfort by providing an easy swing of the injured limb, and to prevent any jarring. It has been found that cases coming from the C.C.S. splinted in this way always arrive at the Base in most excellent condition.

FIG. 17.—A fractured femur splinted at a C.C.S. for transport to the Base. Showing (1) gauze and glue extension to leg; (2) suspension of foot; (3) use of 4 in. paper clips to hold the supporting bands.

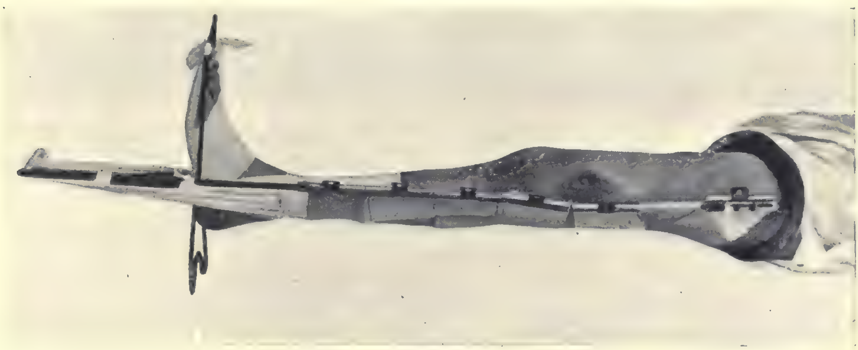


FIG. 18.—A G.S.W. of external condyle involving the knee-joint, splinted at the C.C.S. for transport. Dressings, padding, and bandage have still to be applied.

3. **In injuries to the knee and in high fractures of the tibia and fibula** exactly the same method of splinting may be adopted, except that the splint need not be bent, and that, in the case of the tibia and fibula, the extension may only be carried half-way up the leg (Fig. 18).

4. **In fractures of the tibia and fibula,** except those which are near the knee, and in **injuries in the region of the ankle** the Thomas splint is also the best means of transport; and extension may be obtained by means

of a 'serrated wooden foot-piece' which rides on the side bars of the Thomas and is attached to the foot in the following manner :

The serrated wooden foot-piece. The requirements are (Fig. 19) :

1. A wooden foot-piece 12 in. by 4 in. by $\frac{3}{8}$ in. with a serrated margin and a slot down the centre in which is a bolt holding a movable transverse bar.

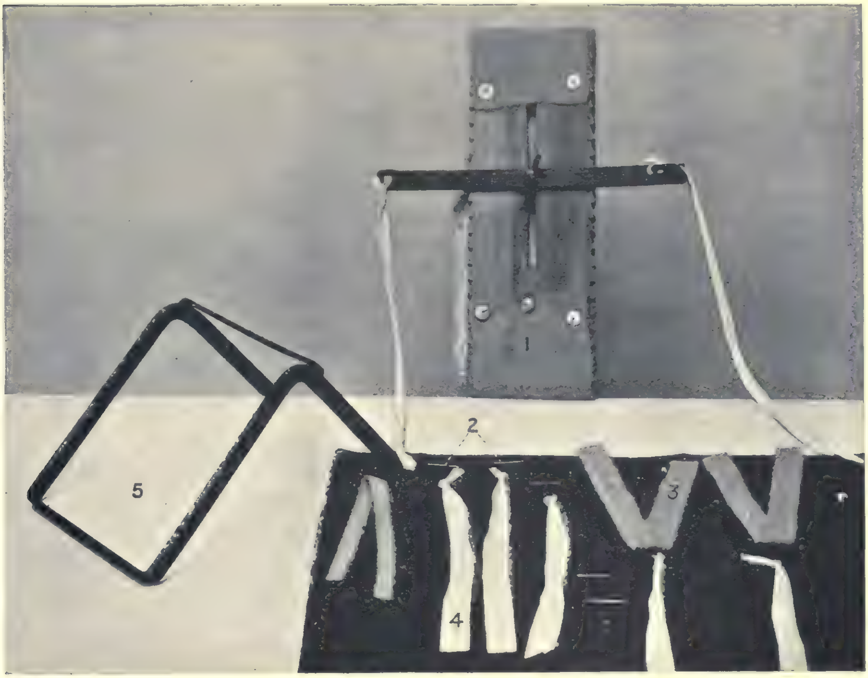


FIG. 19.—Serrated wooden foot-piece, showing

1. The foot-piece, metal cross-bar, carrying tapes for extension. (Note method of padding the foot-piece.)
2. Metal triangles with tapes attached.
3. Flannel strips for glueing across the sole.
4. Extension tapes.
5. Splint prop.

2. Twelve to fourteen metal triangles. These are made out of 1 in. curtain rings squeezed into a triangular shape.

3. Strips of flannel $\frac{3}{4}$ in. broad and about 8 in. long.

4. Some $\frac{1}{2}$ in. tape.

5. A splint prop.

The foot is thoroughly cleaned and glue applied over the sole and dorsum as far as the malleoli. The strips of flannel, each threaded through two small brass triangles, are fixed across the sole of the foot with the

triangles forming a line on either side of the sole and the flannel carried as far up the sides of the foot as possible (Fig. 20). Two very important points must be recognized, viz.:

(1) There should be as many flannel bands as possible without overlapping—usually six or seven—the first behind the malleolus, the second up to the malleolus, the third in front of the malleolus, the fourth, fifth, sixth, and seventh along the sides of the instep.

(2) The bands must not touch across the instep; if they do, a pressure sore is certain to develop there. The serrated wooden foot-piece is padded with a layer of cotton-wool held in position by a strip of flannel bandage placed lengthwise over the wool and pinned to the distal surface by means of drawing-pins (Fig. 19).

FIG. 20.—The serrated wooden foot-piece applied. (Note the method of fixing the foot-piece by means of the flannel strips glued to foot, metal triangles, and tapes.)

The application of the splint and foot-piece is as follows: the limb is threaded into the Thomas splint in the usual way, and the thigh supported by flannel bands. A large pad of cotton-wool is placed inside the bars round the knee and firmly bandaged: this gives stability and support to the upper fragment. The foot-piece is fixed to the sole of the foot by means of tapes attached to the brass triangles on either side and then tied below the foot-piece. The metal cross-piece, to which the tapes for making extension are tied, rides on the side bars of the splint (Fig. 20). This metal cross-piece, being fixed by means of a bolt and butterfly nut, allows rotation outwards to the desired extent, and inversion is obtained by adjusting the extension tapes attached to each end. The extension tapes are tied over the **V** at the end of the Thomas. Flannel bands are adjusted under the leg to give support and to prevent œdema.

A splint prop is attached to prevent the possibility of the wooden foot-piece catching upon bedclothes or stretcher.

During transport the whole splint is slung from two stretcher suspension bars as in the case of fractures of the femur. (The serrated wooden foot-piece is also applied in the above manner for the permanent treatment of fractures of the femur, and will be found illustrated in that section, p. 120.)

5. **Fractures of the tarsus and metatarsus** travel best in a Thomas splint with the foot suspended from a foot-piece by means of gauze glued to the dorsum and sole of the foot, or even glued to the toes alone ; the splint being kept in place by means of glue and gauze extensions from the ankle to the knee, and the whole limb supported by flannel bands clipped to the side bars. These cases require the foot to be kept at right angles and immovable.

II. SPLINTING OF FRACTURES OF THE FEMUR AT BASE HOSPITALS

Upon arrival at the hospital where the main treatment of a fracture is to be carried out, it is first of all necessary to make a very careful examination of the injuries. A good X-ray in two directions is essential. It is frequently advisable to take the patient into the theatre and to give a general anæsthetic so that the wounds may be thoroughly examined, the position of the bone fragments as shown by the X-ray plate carefully verified by external palpation, any further drainage or septic foci attended to, and the limb splinted. Many cases coming down from the C.C.S. on the fourth to the fifth days, however, when properly splinted, only require fresh extensions put on in the ward and the limb slung to the suspension frame ; but a raised temperature and pulse rate upon the morning after admission always calls for a thorough investigation under an anæsthetic by the surgeon. The earlier the cases arrive at a permanent hospital, the better as a rule is the prognosis.

Throughout this stage of treatment frequent X-ray examinations of the fracture are essential. The X-ray plant must be portable so that the patient need not be moved from his bed until there is some bony union (Fig. 40). The methods of splinting used at the Base often do not permit of the patient being moved except for major operations.

A. Fractures of the upper third of the Femur. A net frame has been found the most satisfactory method of treating these extremely serious injuries. The great difficulties in dealing with this class of fracture have lain in the treatment of the wound itself, and in the grave danger of shock from pain when dressings have to be done. The problem throughout has been that of devising some form of splint which necessitates as little movement of the patient as possible during the dressing of the wound or for nursing purposes. Various splints have been used at

different times, such as the Hodgen splint, two Thomas splints tied at the rings to ensure abduction, and special beds of canvas slings: these and other different devices have led to the evolution of the net frame, which excels them all in ease to the patient, in prevention of deformity, and in securing accessibility to the injured area with the minimum of movement. The frame is best understood by a study of the accompanying photographs (Figs. 21 and 22).

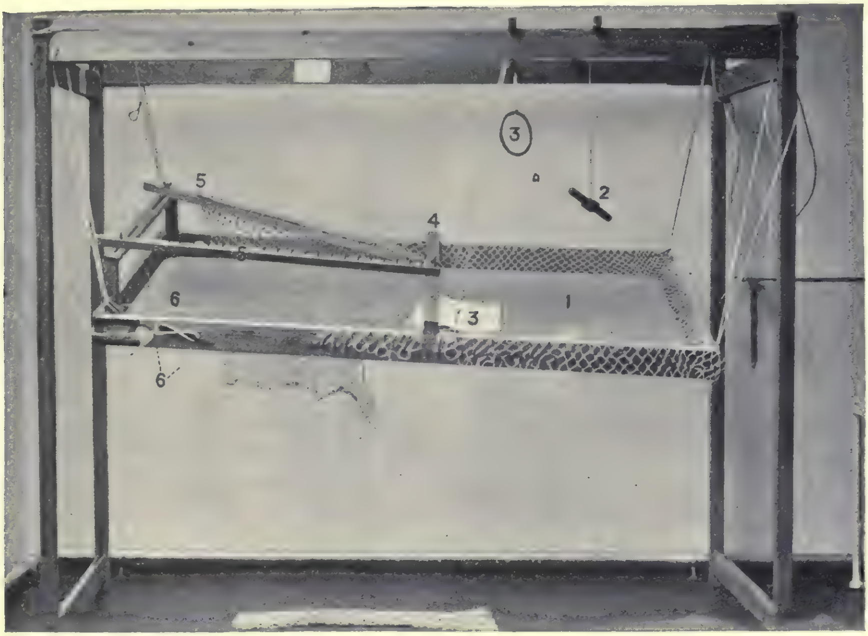


FIG. 21.—The net frame.

1. Body net hooked over the round-headed screws at sides and at head of frame.
2. Handle for patient to raise his shoulders.
3. Handle, cords running over pulley and body sling (for patient to raise pelvis).
4. Umbilical bar.
5. Leg abduction bars.
6. Cord used for pulling edge of body net downwards.
7. Overhead suspension frame.

Description of the Net Frame. The apparatus consists of:

(1) An oblong wooden frame 6 ft. 6 in. long by 4 ft. 6 in. wide with a transverse bar, called the umbilical bar, 3 ft. from the head end of the frame. From this umbilical bar to the foot end of the frame run the two leg abduction bars, which are adjustable, both at the umbilical bar and at the foot of the frame. The head and sides of the frame and the leg abduction bars are studded at $1\frac{1}{2}$ in. intervals with round-headed screws,

over which the netting is attached. The foot of the frame is pierced with holes, through which the extensions are taken according to the degree of abduction required. Three pieces of netting, of $1\frac{1}{2}$ in. mesh, made of $\frac{1}{8}$ in. cord, support the body and the two legs. Attached to the body net are two cords which are used to pull the edge of the net over the buttocks.

(2) A handle for the patient to lift his shoulders.

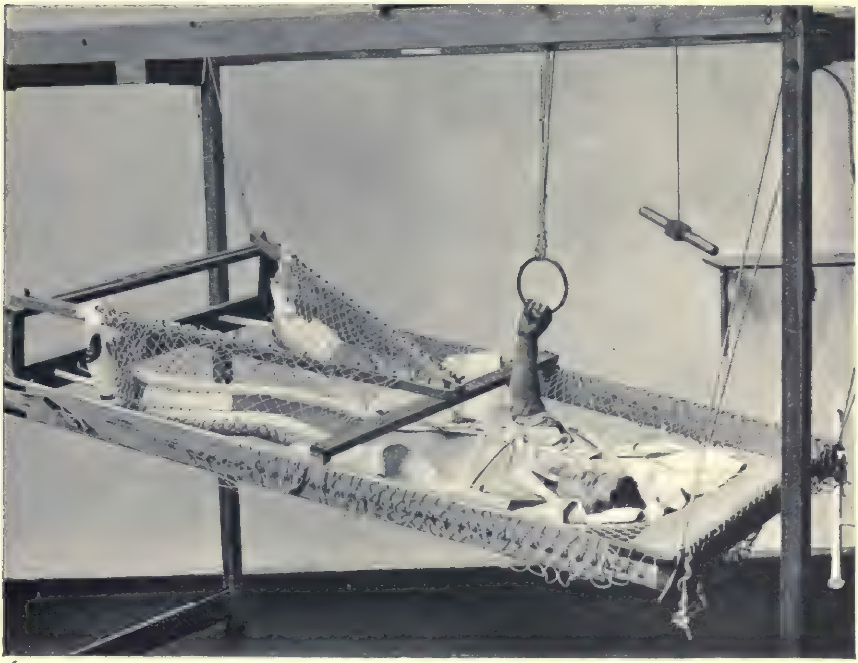


FIG. 22.—Patient in net frame. Note method of obtaining extension by tying leg extensions through foot of frame, and by lowering the head of the frame.

(3) A handle and cords running over pulleys and attached to a canvas body sling. It is by this means that the patient himself holds up the pelvis whilst dressings are being done or a bed-pan used. The canvas sling should be just wider than the body with a metal rod or spreader at each side. The **S** hooks on the cords can be fixed to these metal rods, and the cords run over the pulley which is attached to the suspension frame. The whole frame is suspended by the four corners either to the roof of a hut or to a four-post suspension as in the photographs.

The method of application is extremely simple. The patient can be fixed in the frame immediately after any operation has been performed and while still under an anæsthetic. (During transport from the theatre

to the ward, an ordinary Thomas should be used.) If operative work is unnecessary, the frame can be applied without an anæsthetic.

Application of the Frame. The following is the method of application: A hard table (a trestle table) is prepared by putting on it the body

Figs. 23, 24, and 25.—X-rays to illustrate fractures of the upper third of the femur.
Fig. 23.—Cpl. B. two weeks after injury.

net covered with a blanket folded into four and a draw sheet folded into two. The leg nettings are put into place in an abducted position and padded either by means of a double layer of gamgee, or by a long narrow feather pillow. The patient is prepared by having glue and gauze extensions applied to both legs as far up as the knee, and glue and gauze

suspensions to both feet, and is then lifted on to the table and laid on to the padded netting. The frame, held by two or four orderlies, is put over him and lowered until the umbilical bar is over and touching the umbilicus. The amount of abduction is determined and the abduction

Fig. 24.—Cpl. B. six months after injury.

bars are fixed accordingly. (Usually this is in full abduction, but the amount will be corrected by the X-ray, which should be taken immediately after the patient has been finally fixed in the frame.) The extensions are carried through holes at the foot of the frame and tied. The feet are suspended to the abduction bars. The body net is fixed over the round-headed screws along the sides and head of the frame and

pulled as taut as possible. Each leg net is fixed over the screws on the abduction bars. When suspended, the umbilicus should be 4 in. from the umbilical bar and the patellae 4 in. from the abduction bars. Lastly, the cords attached to the edge of the body net are firmly pulled down,

Fig. 25.—Pte. J. two months after injury.

bringing the net over the buttock, and are fixed to the foot end of the frame. The frame and patient are now lifted from the table and suspended with the head of the frame at a lower level than the foot. The amount of extension on the injured limb will depend on the amount that the head of the frame is lowered below the foot of the frame. The amount required is usually 12 in. to 18 in., and is determined by the

state of the fracture as shown by the X-ray and also by the measurements of the limb. The extension caused by lowering the head of the frame 18 in. is sufficient to pull out any fracture of the upper third of the femur to full length within three days. When the limbs are equal in length it may be advisable to raise the head until it is 12 in. below the feet.

Special Points to be observed in using the Net Frame.

1. There is one deformity which may occur, and which only has to be known to be guarded against, viz. an adduction deformity of the upper fragment, which is caused by too much extension. In this deformity, when shown by X-ray, lengthening on the injured side has always been found.

2. Care must be taken that there be no inward rotation of the lower fragment. This is guarded against by keeping the foot well everted. The amount of rotation outwards of the upper fragment is shown by the extent to which the lesser trochanter is seen on an X-ray plate taken with the tube placed absolutely vertical to the fracture.

3. The umbilicus and patellae should always be kept at a fixed distance from the umbilical and leg bars, usually about 4 in.

4. It is most important that the patient should have only one small head pillow. If a mass of pillows flex his trunk on his thighs the whole action of the frame is lost.

5. The patient should be taught to help as much as possible by raising his body during dressings.

The net frame should be used until union, as shown by fairly dense callus on a good X-ray plate, has occurred. This takes place in about 8 to 10 weeks. Thereafter, treatment is carried out on a Thomas leg splint, as described in dealing with the second stage of fractures of the shaft (p. 119).

B. Fractures of the Shaft of the Femur.

Application of the bent Thomas Splint. The splinting of fractures of the shaft of the femur may be carried out as follows: A Thomas splint with a well-fitting ring, a serrated wooden foot-piece, and a splint prop are the essentials (Fig. 11). Glue and gauze extensions (p. 99) should be applied from the ankle up to the knee, and preparations made for the application of a serrated wooden foot-piece by gluing the flannel strips with the metal triangles on to the foot (p. 103). The reason for having two extensions is that after about ten days there is so much atrophy of the injured limb that the leg extensions become loose, and require to be re-applied just at the time when the least bit of movement of the fractured bones will do much harm. By this means all the strain

can be put on the foot-piece during the time necessary to apply the leg extensions. A further advantage of the two extensions is that, if the patient complains of pain from either extension, a greater pull can be put on the less painful one for a few hours.

The Thomas splint is bent to an angle of 160° exactly at the level of the knee-joint. The reason for this bending is twofold: (1) it relaxes the muscles of the calf, thus lessening the tendency to posterior displacement of the lower fragment, and (2) it brings the axis of traction of the extension into the line of the lower portion of a normal femur, and thus tends to restore the normal anterior bowing. In applying the splint, the surgeon makes firm traction in a line well above that of the

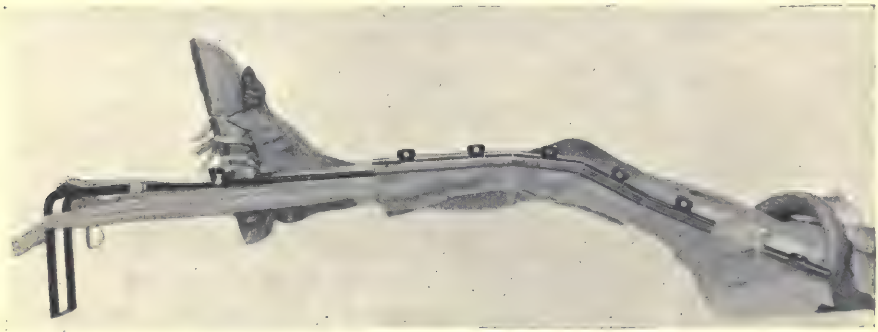


FIG. 26.—Application of the bent Thomas splint at the Base. Showing master band in position, other bands supporting limb, and double extension, the leg extension being tied round the splint prop below level of side bars.

lower end of the splint, and counter-extension by pushing the ring of the splint against the ischium. The first suspension flannel band (the 'master band'), which should be of double thickness of flannel, is fixed at the level of the fracture, and the limb is lowered across this band until the malleoli are below the level of the side bars. This ensures the reposition of the normal anterior bowing of the femur. Full extension is maintained while the extension gauze is fixed by tying it round the splint prop, which is attached to the end of the splint. The limb is firmly supported whilst the rest of the suspensory flannel bands are applied. These must touch edge to edge from the buttock to a hand's breadth above the heel, but must not be put on so tight as to render the 'master band' loose. These bands form a perfect posterior splint. The wooden foot-piece is now tied on to the foot and rotated out according to the amount of rotation outward of the upper fragment (Fig. 26).

In all fractures of the shaft of the femur the upper fragment tends to rotate outwards through the arc of a circle the radius of which is

formed by the neck of the femur: therefore to get an anatomical reposition it is often necessary to rotate the lower fragment outward very considerably. The posterior displacement is governed by the lift from the 'master band'. By bending the splint and carrying the extensions below the level of the side bars (Fig. 26), the tendency towards posterior displacement of the upper end of the lower fragment is reduced. Provided the ring be reasonably small there is never any trouble with

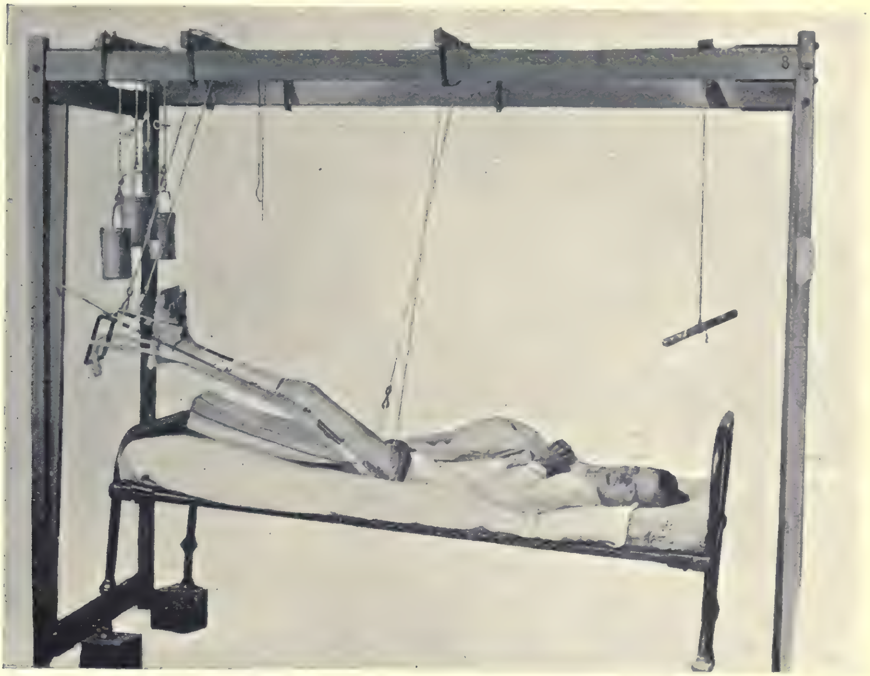


FIG. 27.—The method of suspension. Vertical pull obtained by means of weights and pulleys, horizontal pull by raising foot of bed and tying splint to vertical bar.

alinement so long as sufficient extension is maintained. The limb must be measured frequently to make sure that the length is correct.

Importance of the Suspension of Splints. The above method of splinting depends almost entirely upon extension to maintain a good position of the bone, and the amount of extension required is usually very considerable; therefore the counter-extension on the ischium involves grave danger of pressure sores under the ring.[1] On the other hand, when the ring is large enough not to cause any circular constriction of the

[1] At all times most careful instructions must be given with reference to the cleaning of the ring. This should be done twice a day by means of a strip of soaped bandage worked transversely round the ring, and by cleaning and shifting the skin under the ring.

I 2

thigh, any movement of the patient, even twisting in bed, moves the upper fragment slightly. It is for these reasons that an essential part of the treatment of these fractures, introduced with such successful results by Major Maurice Sinclair, is to suspend the limb and splints so that the splint will easily follow all movements of the body.

The two important factors in this method of suspending a fracture are :

(1) A vertical pull, by means of counterpoise weights attached to the ring and end of the splint by cords and pulleys, to lift the limb and

FIG. 28.—Suspensions in a 'hutted hospital'.

splint from the bed ; and (2) a horizontal pull by making the body weight pull against a fixed point, which must be beyond the end of the splint in order to relieve the pressure of the ring upon the skin (Fig. 27).

In hutted hospitals these suspensions and extensions can be made from the roof and from a vertical bar fixed at the end of the bed (Fig. 28), but in home hospitals it is necessary to have some sort of suspension apparatus such as a Sinclair suspension frame (Fig. 27) or Balkan bar. The suspension frame is, up to the present time, the most efficient method. It consists of a four-post frame, 18 in. longer than the bed and an inch or two wider. It must be well made and stable.

(1) **The vertical pulls** are attached to cross bars which are adjustable in order that they may be directly above both ends of the splint. The

counterpoise weights are carried to the end of the frame so as to be out of the way. These weights should not be too heavy—a 5 lb. and a 4 lb. weight from the ring, the heavier being on the inner side, and two 4 lb. weights from the foot of the splint are usually sufficient. Any tendency

FIGS. 29 and 30.—X-rays illustrating fractures of the shaft of the femur.
Fig. 29.—L/c. P. on admission.

of the splint to tilt inward or outward can be dealt with by adjusting the amount of weight on the inner or outer sides.

(2) **The horizontal pull** is obtained as follows: A movable vertical bar opposite the end of the bed serves to fix the lower end of the splint. The foot of the bed is raised 10 in. from the floor and the end of the

splint 10 in. above the bed. The bar is adjusted so as to be exactly opposite to the end of the splint. The patient is brought as far as possible towards the foot of the bed and the end of the splint is tied firmly to the

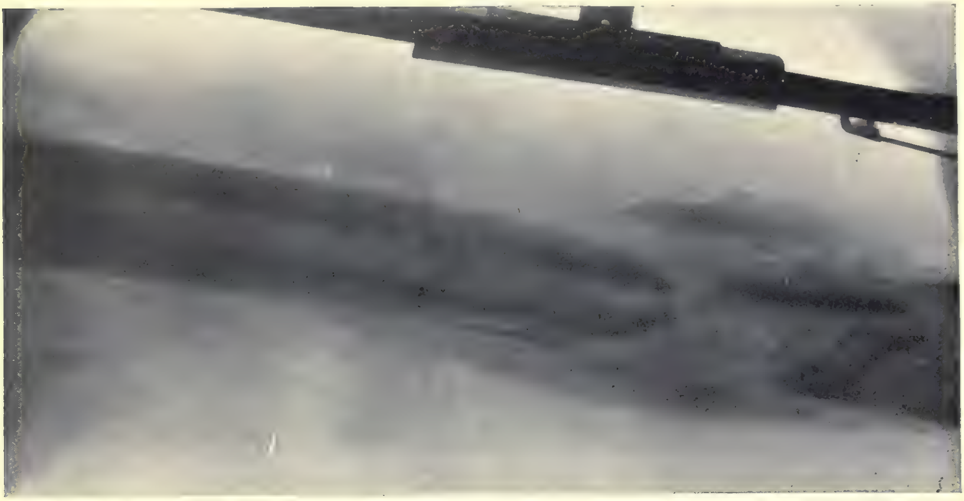


Fig. 30 a.—L/c. P. after three months' treatment. A. P. View.

Fig. 30 b.—L/c. P. after three months' treatment. Lateral View.

bar. The shortness and rigidity of this tie are important in order that, during the acute stage at least, the lower end of the splint should not swing. All movements of the patient will tend to pull on the upper fragment, the body and limb moving in the radius of a circle having the upright bar at the end of the splint as its centre. For the past two years no weight

and pulley extension has been used, it being found that the fixed point of extension at the end of the splint holds everything so much more rigid. As well as giving comfort to the patient and great improvement in controlling the fracture, the suspension of the Thomas splint is an

Fig. 30 c.—Lateral Skiagram of end result of fracture of lower third of femur.

enormous saving when nursing is considered, because dressings and bed changing can be done by one nurse. Further, the general condition of the patient is invariably improved by his being able to move himself about in bed without giving rise to pain. It is most important that one head pillow only be used whilst full extension is being maintained.

Usually acute sepsis will have subsided within a week of the patient being splinted. In cases received during the first week after injury, full length is invariably obtained by the end of 24 hours, and frequent re-measurements should be taken to guard against over-extension.

In dressing any of these fractures, it is most important to make sufficient strain on the bands above and below the fracture so that, when the ' master band ' is released in order to get at the dressing, the limb will not sag. If there is a long wound, sectional dressings 4 in. wide should be used and only one band removed at a time (cf. Fig. 31).

Further Treatment in straight Thomas Splints. As soon as there are clinical signs of union and the X-rays show a marked shadow of callus (usually after a period of six or eight weeks), the splint may be changed to a straight Thomas with a leg extension and a serrated wooden foot-piece as described above (p. 106) (Figs. 32 and 33). Under these circumstances there is very little danger of shortening, therefore the amount of traction may be lessened. Extension from the leg alone

is sufficient to hold the splint in position, but the foot must be rotated outward by means of the serrated foot-piece to prevent torsion of the newly-forming callus. Massage and graduated contraction of the quadri-

FIG. 31.—Showing a sectional 4 in. dressing and the method of application when a long posterior wound is present.

FIG. 32.—Later treatment of fracture of femur in straight Thomas splint. Note double extension and outward rotation of foot.

ceps and passive movements of the joints can now be carried out, and when muscle tone begins to return mechanical means of allowing flexion at the knee-joint may be used. A good method is to hinge a duplicate of the lower portion of the Thomas splint exactly at the knee-joint (Figs. 34 and 35) ; the extensions and supporting bands are attached to

this hinged portion. The amount of flexion is limited by tying the end of the hinged portion to the end of the straight splint. When 30° or 40° of flexion have been obtained passively, the hinged portion may be

FIG. 33.—Straight Thomas splint suspended during later stage of treatment of fractured femur.

attached to a cord running over a pulley and the patient encouraged to extend his knee himself by pulling upon the cord (Figs. 34 and 35).

C. Fractures of the lower third of the Shaft and in Region of the Knee-joint.

The treatment of these fractures is complicated by the proximity of the knee-joint. The original injury often involves the knee-joint either by fissures running from the site of fracture into the joint, or by the

track of the missile opening up the joint after having gone through the bone; or the synovial cavity may have been opened through tearing of its prolongations by bone splinters.

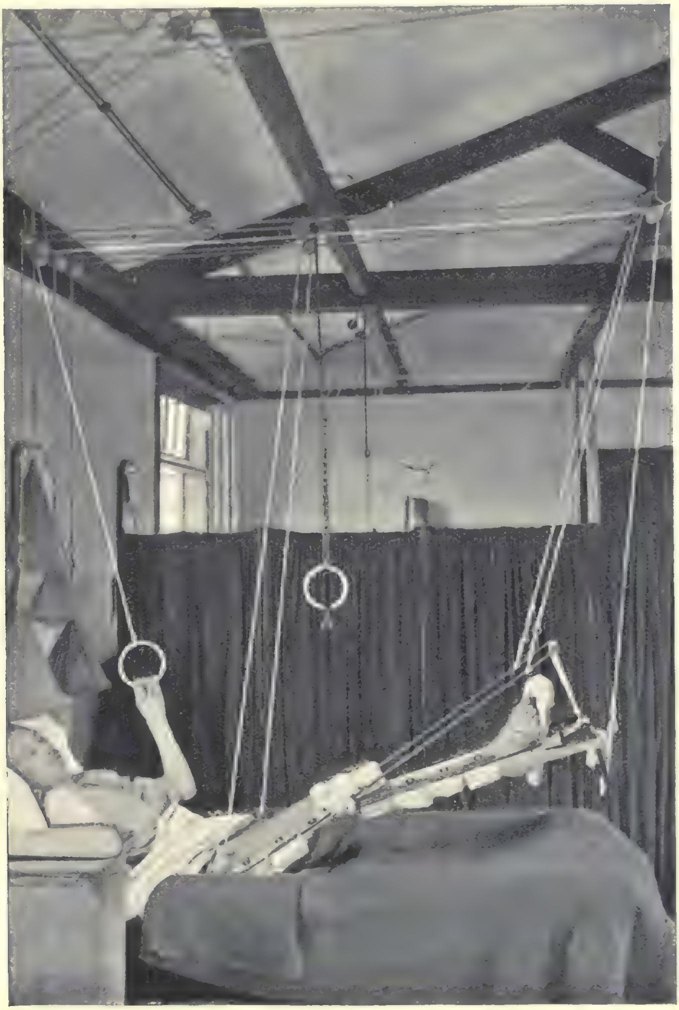


FIG. 34.

FIGS. 34 and 35.—Knee-flexing attachment. The amount of flexion is limited by the cord between the splint and the flexing bar. The cord and pulleys enable the patient to move his own knee.

The treatment of the acutely septic knee-joint is dealt with in another chapter (p. 297). In the splinting of these cases it is very necessary to overcome the posterior displacement of the upper end of the lower fragment. This is done by efficient early extension. A small-ringed

Thomas leg splint should be used, bent to an angle of 160°, and both foot and leg extensions applied. Full use must be made of the body weight by fixing the end of the splint and by raising the foot of the bed, and the 'master band' must be most carefully adjusted. After the

FIG. 35.

patient has been splinted and traction maintained for 48 hours a lateral X-ray must be taken, and, if there be still posterior displacement of the lower fragment, it may be overcome in two ways: (*a*) extension may be increased by tilting the foot of the bed higher; or (*b*) increased flexion

of the knee may be obtained by lowering the foot on the foot-piece and loosening the bands supporting the leg. Efficient extension and a tight band behind the fracture invariably reduce the deformity in its early stages, unless the X-rays show fragments of bone blocking reposition. In such a case these fragments must be removed.

When sepsis has subsided and there is some evidence of callus, these knee cases should be gradually brought into full extension. This is done by gradual adjustment of the bands and foot-piece in the bent Thomas until a straight splint can be applied. Sometimes several weeks are

FIG. 36.—Walking calliper splint and boot. The boot illustrated above has been raised to compensate partially for shortening of an injured limb.

spent in this straightening process and the rate of progress is guided by any sign of reaction such as pain or temperature.

Walking Calliper Splints. The next stage in the treatment of a fractured femur is that of getting the patient walking in a walking calliper splint (Figs. 36 and 37). The best time for this varies with the amount of destruction of the bone. If there has been much comminution it is necessary to wait until a good X-ray plate shows trabeculation through the callus. This does not occur until the fourth or fifth month. If there has been a clean fracture, and by palpation the bone feels firm, and there is very little tenderness at the site of fracture, and the X-rays show good callus formation, a walking calliper may be applied even at the end of the third month.

A walking calliper splint consists of a ring, carefully padded and covered with leather, and two side bars of $\frac{3}{8}$-in. round iron attached to either side of the ring and fitted at the other end into the heel of a boot. Leather supports to fix the knee in a position of full extension are also

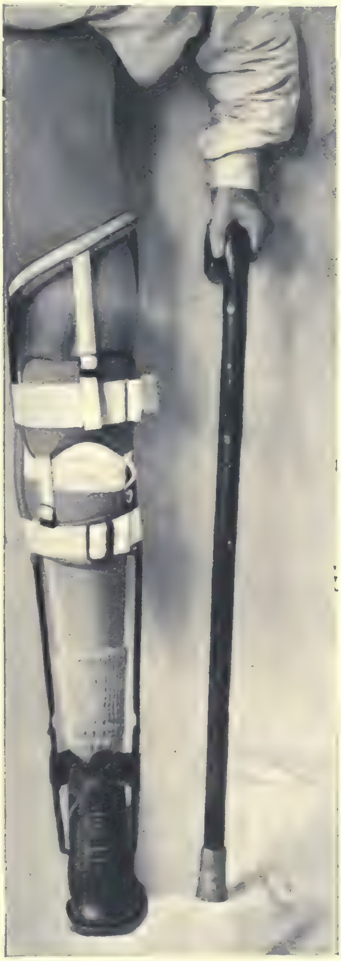


FIG. 37.—Walking calliper splint applied.

necessary (Fig. 36). Essential points in the fitting of a calliper splint are: (1) that the ring must exactly fit the upper portion of the patient's thigh, taking its pressure from the tuber ischii, and (2) that the side bars must be just longer than the length of the injured limb, in order that when the boot is fitted and the splint applied the patient's heel shall bear no weight. (If there be much shortening the boot should

be raised to compensate for a part of this.) It is most important that no weight should be borne by the recently united bone. The callus of septic fractures remains soft and easily becomes deformed for many months after it is apparently firm. The most efficient stimulus to rapid hardening of the union is to make the patient use the limb, but care must be taken that no bending can occur at the fracture. The patient is allowed up and encouraged to walk with a stick only. After any severe infection, the patient must be kept in his walking calliper for at least six months. This point is most important, because months of the most careful attention are wasted by the removal of a walking calliper too soon : the indications as to when to leave it off are good muscular development of the limb, no pain in the callus on deep pressure, and an X-ray plate showing trabeculation right through the new bone formation. During the period that the patient walks with the calliper every effort must be made to obtain good controlled movement of his joints, especially of the knee-joint. This is done by massage, &c. with the calliper removed, and by encouraging the patient to move the limb freely when in bed. The heel and sole of the boot on the sound limb should be raised so that the total length of the limb and boot is $\frac{1}{2}$ in. longer than on the injured side. This prevents the toe on the injured side catching the ground during walking.

Difficulties encountered in the Splinting of Fractured Femurs. Many difficulties arise during the treatment of cases of fractured femur, such as :

1. **Incorrect Alinement.** This can be adjusted by fitting a small ringed splint, by increasing the extension on the lower fragment to get full length, and by the use of bands pulling the fragments towards the side bars of the splint according to the direction indicated by the X-ray.

2. **Posterior Displacement** of the upper end of the lower fragment, or the loss of the normal anterior bowing of the femur. This can be corrected by (*a*) increasing the extension, (*b*) tightening the 'master band', (*c*) dropping the malleoli still farther below the side bars.

3. The most serious difficulty arises where there are multiple wounds or multiple fractures which prevent the ordinary extension being used. It is only in these cases that the use of other methods of obtaining extension is to be recommended.

Mechanical Methods of Extension. The following are some of the mechanical means of obtaining the extension when the glue and gauze method is found impracticable (Fig. 33) :

1. Extension calliper and guards for the malleoli or condyles.
2. Major Pearson's method with ice-tongs calliper.
3. Major Sinclair's stirrup.
4. Screws into the tibia and a direct pull.

1. **Extension Calliper and Guards** (Figs. 38 and 39). A well-made suitable sized engineers' measuring calliper is fitted with two 'extension guards'. These extension guards are made of a 3 in. by $\frac{1}{2}$-in. flat rod of

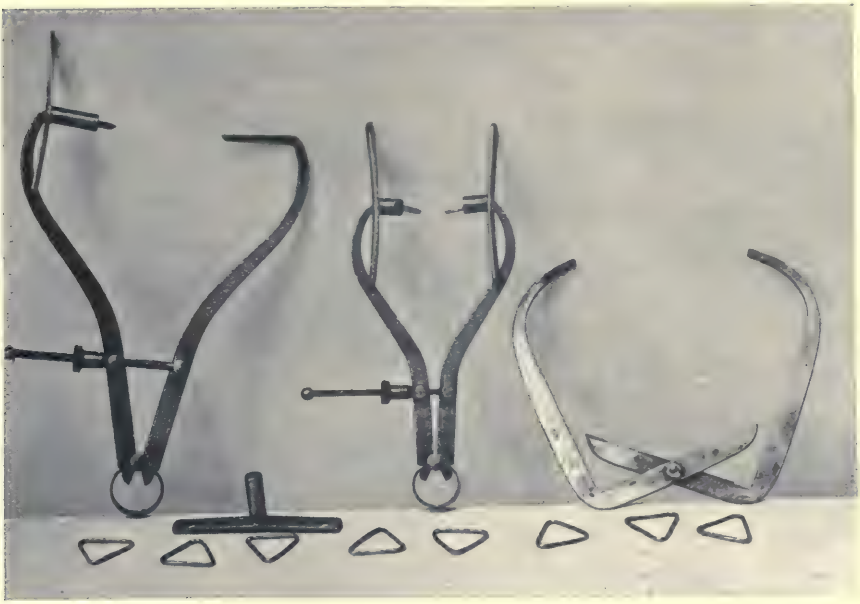


Fig. 38.

1. Extension calliper for use in the condyles. Shows one guard in place.
2. Extension calliper for use in the malleoli.
3. Metal stirrup for use over the tendo Achillis.

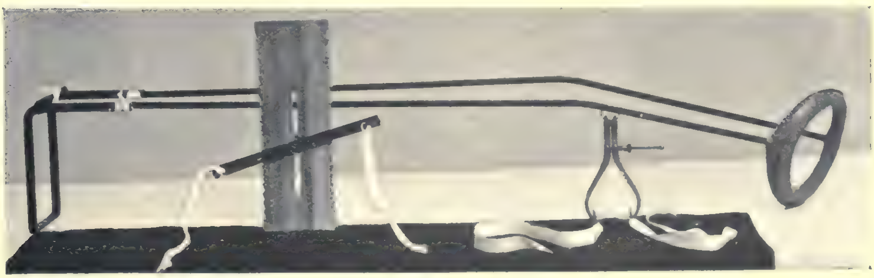


Fig. 39.—Splint, calliper, and foot-piece, extension tapes tied to foot-piece and calliper.

metal with a small metal tube welded at the centre through which the ends of the calliper are to be inserted into the bone.

The technique of the operation is as follows: Incisions 1 in. long are

made (*a*) if for the malleoli, at a point 1 in. above the tip of the internal malleolus and at a point exactly opposite, above the external malleolus; (*b*) if for the condyles of the femur, at a point just above the adductor tubercle and at a point exactly opposite on the outer condyle.

The skin and subjacent structures at these points are cleanly cut through down to the bone; the small tube on the extension guard is

FIG. 40.—Splint, calliper, and foot-piece applied, portable X-ray apparatus being used.

slipped into the incision with its end bearing upon the bone; a $\frac{3}{16}$-in. drill marked at the point that will be reached when it projects $\frac{1}{5}$-in. beyond the end of the tube is used to make a hole into the outer layer of the bone, the assistant taking great care that the guard does not move. The calliper is then fitted through each guard with its end projecting into the bone, and a sterile dressing is put under the flanges of the guard and round the limb, the whole being very carefully padded and bandaged. Traction is made by means of strong tape from the extension guard (Fig. 40).

This form of extension can be left in position until bony union has begun. The danger from osteomyelitis is slight because of the small amount of bone affected by the operation. The further treatment of

the fracture is upon the same principles as when glue and gauze is used, the extension from the calliper taking the place of the extension from the leg. It is advisable to apply a serrated wooden foot-piece which will maintain the outward rotation of the lower fragment and keep the foot at right angles.

2. **Ice-tong Calliper.** In Major Pearson's method the calliper is used in the condyles of the knee from points the same as those detailed for the method just described. The skin having been incised, the points of

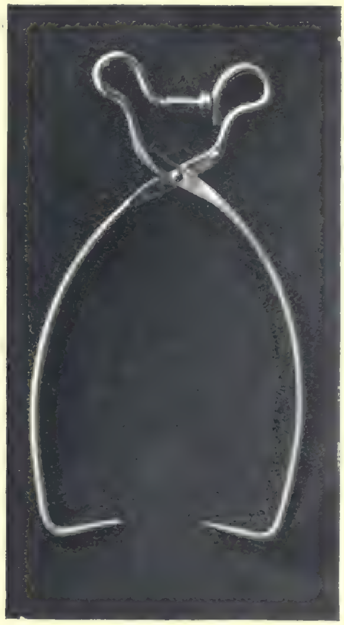


FIG. 41.—Major Pearson's ice-tong calliper.

the calliper are adjusted on to the bone to take a hold, penetration being prevented by a locking screw on the stem of the tongs. Extension is taken directly from the calliper to the end of a straight Thomas splint, the leg and foot being supported on a hinged 'flexion piece' so that movements of the knee may be begun at any moment. The foot is suspended at right angles by glue and gauze to a suspension foot-piece attached to the flexion rod.

3. **Major Sinclair's Stirrup.** This method is sometimes useful when wounds prevent the use of mechanical traction on the condyles and malleoli. Its chief virtue is that no bone is affected. The stirrup is inserted through incisions on either side of the tendo Achillis, and when the jaws of the instrument are closed it cannot open so long as extension is maintained from the transverse base. The danger in its use is that

of damage to the tendo Achillis; and this form of traction should not be maintained for more than three weeks, which is sufficiently long to give good extension over the acute septic period.

4. **Screws into Tibia.** This method is upon its trial, and in the hands of Major Sinclair has given some very excellent results. A special screw $2\frac{1}{2}$ in. by $\frac{3}{16}$-in. is used; two of these are screwed into the tibia an inch below the tubercle, and extension by means of tapes is taken directly from them to the end of a bent Thomas splint.

UNUNITED FRACTURES

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UNUNITED FRACTURES

UNUNITED fractures of the long bones constitute a class of injury comparatively rare in civil practice but made very familiar to us as the results of gunshot injuries. The conditions which cause delayed union or non-union of a fracture are many of them of simple and obvious character, such, for example, as extensive loss of substance or the interposition of soft parts. But there are other circumstances of a more subtle nature, dependent upon the actual structure and mode of growth of bone tissue, which require our preliminary attention.

Special characters of bone tissue. Bone is a highly differentiated form of connective tissue. Among its most important peculiarities are the relatively large proportion of extracellular material, and the dense nature of the same. That is to say, the living active element of bones, namely the cells and blood-vessels, are comparatively scanty in proportion to the huge bulk of earthy salts which have been deposited by the former in the course of growth. Inasmuch as repair of injuries always depends in the first place upon the activity of the cellular elements, and as these lie buried in inert bone salts, it follows that the latter tend to obstruct and retard the formation of new tissue. In the first place, it will always be necessary for an absorption of the bone-salts to occur in order to give play to the more vital elements ; and in the second place, for the restitution of the skeleton, it is necessary that these extracellular elements, i.e. the earthy salts shall be again laid down so as to bridge the gap of the fracture. In the normal growth of the bone three phases of activity may be observed :

(1) A growth in length, which only takes place at the ends of the bone at the period before the junction of the epiphyses with the diaphysis. This element of growth which is so active in juvenile bones is absent in the adult.

(2) Eccentric growth, or growth in thickness, takes place by the deposit of new layers of bone on the surface of the shaft, beneath the periosteum. It is brought about by a layer of osteoblasts on the surface of the dense bone, developing in the line of least resistance, i.e. in the loose connective tissue of the periosteum. Every piece of vascular bone retains this capacity for depositing new bone upon its own surface, and this represents therefore the most important element of osteogenesis in the repair of fractures.

(3) Interstitial growth, or growth in density, is brought about by the bone cells in the vascular canals laying down new deposits of earthy salts. This is always a most important factor both in normal and abnormal bone repairs. Under normal conditions it represents the final phase, when the injured bone, by an interstitial deposit, becomes harder and denser than formerly. But under abnormal conditions this interstitial deposit may often be premature, and then has the effect of making the ends of a broken bone denser and avascular before the gap between them has been bridged over.

Methods of repair. The vital and essential elements in bone repair consist of the osteoblasts and the blood channels in which they lie. Circumstances which destroy the osteoblasts or which hinder their blood supply will delay or prevent union. After a fracture, the multiplication and deposit of the new bone cells takes place in the blood-clot which fills the crevices of the broken bone. Following upon the multiplication of these new bone cells there ought to occur a rapid absorption of earthy salts in the end of the broken bones, a process of osteoporosis. Then follows the union of apposed layers of bone granulation tissue with a deposit of new earthy salts between the young cells and new blood-vessels. This is the formation of callus. Finally, the soft callus is converted into hard bone by the deposit of denser layers of earthy salts, the process of osteosclerosis.

Varieties of wound-healing in bone. Just as with the soft tissues, so with those of the skeleton, healing may be by first intention, or by granulation. Healing by first intention in a fracture requires that the broken bone ends shall be in close and accurate apposition, so that the interval between them, to be filled by new tissue, is reduced to a minimum, and the reconstruction required will be merely the bridging of a minute gap by new bone. On the other hand, when the fragments of a broken bone do not lie in apposition with one another, large spaces and crevices have to be filled up by callus, pieces of broken bone with deficient blood supply will become absorbed or more likely cast off as sequestra, and an extensive reconstruction will be necessary, a reconstruction which may be hindered at any point in its progress, either by an exhaustion of the osteogenetic elements, the osteoblasts and blood-vessels, or by an imprisonment of such elements in avascular connective tissue or sclerosed bone. As with the soft parts scar tissue is the end of all healing, so with the bone. The deposit of scar tissue in and around a fracture, if occurring before the reconstruction of the skeleton is complete, involves an indefinite postponement of sound healing. This is one of the cardinal facts to be borne in mind in the subject of ununited fractures, and is equally important in connexion with its causation, its treatment, and its prevention.

Pathological types of ununited fractures. In the injuries of adult bones

brought about by trauma there are four distinguishable types of ununited fractures.

(1) *The gap fracture.* In this, there has been a complete loss of all the elements of the bone for a portion of its entire thickness. Some mechanical factor has prevented the remaining fragments of the bone from coming together. Usually this factor consists of an unimpaired fellow bone, or it may be that gravity or extension treatment has served to hold the bones apart. The actual bone fragments after a time become rounded, and the marrow-cavity plugged by callus. The whole shaft of the bone, whilst it retains its original shape, becomes light and porous.

(2) *Fibrous tissue intervention.* In this type of non-union there has been a spiral or oblique fracture and the ends of the bone have become wrapped round with periosteum and other forms of connective tissue, which form a smooth covering for the bone surfaces and which effectually prevent bony union of the same. Such a fracture has often been immobilized for a long period, in plaster of Paris or some other splint, and except for a general atrophy of the bones and muscles there is very little change observed in the tissues.

(3) *Pseudo-arthrosis.* As this name implies, a false joint has been developed at the site of the fracture. Such a type of non-union is especially liable to occur in a bone like the humerus, where mobility in all directions is unrestricted. Its main pathological characteristic is the coincidence of great hypertrophy of unhealthy elements of repair with the non-union of the fracture. That is to say, both bone fragments are thickened and present a disorderly mass of sclerosed bone and fibrocartilage, which has a smooth surface towards the false joint and a ragged edge away from it. In old-standing cases there may be an actual joint cavity at the seat of fracture, filled with a glairy synovial fluid.

(4) *The atrophic type of non-union.* This type is usually the outcome of long-continued sepsis in which destruction of bone cells, blocking of blood-vessels, and absorption of bone salts have gone on side by side. There is no great gap between the bone ends, neither is there any evidence of exuberant and unhealthy bone repair. The bone fragments lie end to end, indolent and inactive.

The division of pathological varieties of ununited fractures into these four types is somewhat arbitrary, and is employed in order to emphasize the four most important features of this condition, namely, the loss of substance, fibrous tissue intervention, the formation of a fibro-cartilagenous false joint, and an indolent atrophy. It will, of course, be understood that in many cases two or more of these features are combined in the same case.

I. THE CAUSES OF NON-UNION AND THE NATURAL RESULTS OF THE SAME

There are four obvious causes of non-union of fractures, but the relative importance of each of these varies greatly in any given series, and therefore the figures here given must be understood to have only a relative significance and to apply chiefly to gunshot injuries.

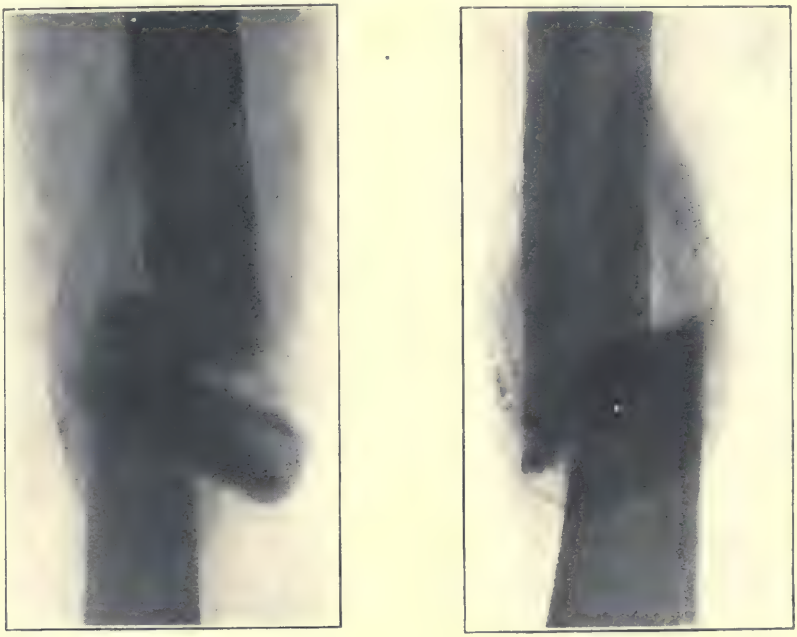
These four causes are :

(1) Primary loss of substance.
(2) Displacement, or fibrous tissue intervention.
(3) Necrosis.
(4) Sclerosis.

1. **Loss of Substance as the most important Factor in the Production of Non-union of Gunshot Fractures.** This cause is the most important, and accounts for more cases than all the others put together, viz. 56·6 per cent. In the bones—e.g. the radius, ulna, and tibia—where there is another parallel bone which maintains the length of the limb and prevents contraction from bringing about a closure of the gap, the reason for loss of substance leading to non-union is obvious. Whatever may be our conceptions as to osteogenesis, we cannot be blind to the fact that in the adult, a gap in one of the long bones remains unfilled by new bone in a large number of cases. Neither the periosteum nor the cut ends of the injured bones produce any appreciable callus repair. In fact I would go so far as to say that I have seen no evidence of the reconstruction of the diaphysis of an adult bone when a considerable portion of it has been removed. And this in spite of the fact that I have been looking for such evidence very closely, and asking for it from others. It is impossible to say to what extent the loss of bone is actually occasioned by the original wounding missile, or how far it has been due to primary surgical interference, or to later sepsis ; but there can be no doubt that in a great many cases the bone has been very freely sacrificed by operative attack, as is shown by clean sawn ends, and also by statements on the field cards such as ' Bone fragments freely removed ', &c. It would be quite unfair to criticize such treatment without knowing the circumstances which appeared to justify it, and I have no doubt that rapid clean healing has often been promoted thereby, and that limbs and even lives have been saved which would have been lost by more conservative methods. But it is useless to shut our eyes to the fact that this free removal of bone does almost inevitably lead to an ununited fracture which causes a very prolonged loss of function, and which requires a most difficult and uncertain operative treatment for its final restitution.

There is a large number of cases of fracture the union of which is

delayed by sequestra, and in which rapid union takes place after the removal of the dead bone. This observation leads to the conclusion that, whilst primary removal of all loose fragments is likely to cause an ununited fracture, if the case is freely drained and properly immobilized, and left until the dead bone is naturally differentiated from the living, before the removal of sequestra, natural union will generally occur. It is a monstrous misuse of terms and a flagrant begging of the question to call all loose fragments of bone in a comminuted fracture 'sequestra',



FIGS. 42, 42 A.—Right and left femurs of an officer who fractured both thighs and his skull in a flying accident. The photos are taken four weeks after the accident, and illustrate the rapid formation of callus under the influence of constant movement. The patient was delirious and violent for all this period, was treated by 20 lb. weight extension applied by tibial transfixion to each leg. He obtained a perfect functional result, and was able to play tennis four months after injury.

and to teach that primary subperiosteal sequestrectomy should be the treatment. I have elsewhere published a sufficiently large series of cases of consecutive gunshot fractures of the femur to demonstrate that the cases of comminution heal with rather greater rapidity than those of a more simple nature, and I have also given experimental evidence to the same effect. A study of cases, in which a large removal of bone fragments has been carried out, is the natural complement of the experimental and clinical evidence as to the importance of the bone fragments in bringing about natural repair.

To sum up: Always supposing that free drainage has been secured, with a removal of gross dirt and septic foreign bodies, then the leaving of bone fragments in a comminuted fracture is the surest way of securing natural and rapid repair, whilst removal of these fragments is the surest way of producing an ununited fracture.

I believe that it is extremely rare for a piece of bone to be severed from all vascular supply by trauma, and I use the term loose fragment, as implying that a piece of bone is separated from the main shaft but not from organically connected soft parts. I have no belief in the value of

FIG. 43.—Femur of *Case* 47 treated by a bolted plate after seven months' non-union due to displacement. Perfect result, but the plate had to be subsequently removed on account of the formation of an abscess.

a piece of bone separated from its blood supply as an agent of repair, and if such separation is beyond all doubt, then surely the fragment is better away from a septic wound. But it is far better to wait for a few weeks for natural differentiation of dead bone, than to expose and search for sequestra by manipulations which endanger the vascular connexions of the fragments in question. Apart from the failure of the wound to heal, there is a ready method of recognizing ' dead bone ' in a fracture, and this is usually available in four to six weeks after the receipt of the wound. It is by means of the X-rays. The region of the injured bone rapidly undergoes changes in density, all the living bone becoming rarefied, whilst the dead bone retains its original opacity.

The radius, ulna, and humerus are the three bones which most often exhibit non-union from loss of substance. In the case of the two former, when the fellow bone is intact, the explanation is that contraction cannot take place. With the humerus, it is the weight of the arm which prevents

this contraction, and it is not easy to devise a suitable splint or sling which will obviate this whilst allowing of the daily dressing. One of two devices may be employed, either an abduction arm splint in which

FIG. 44.—Femur of Lt. J. before operation.

FIG. 44 A.—Same bone after operation. The large loose fragment was twisted round and had to be replaced. It was bolted to the upper fragment, and this was then fixed to the lower by a clipped plate.

the humerus is kept almost in a horizontal plane, or else a special wire cradle-splint by which the forearm is slung to the shoulder. The former is suitable for fractures of the upper, and the latter for those of the middle and lower, portions of the shaft. The tibia is not so frequently the seat of an ununited fracture from loss of substance, because usually the fibula

is also broken either primarily or secondarily, and this allows of the apposition of the broken surfaces. In the case of a small gap in the tibia with a large anterior wound which will make grafting difficult, it is better to do an osteotomy of the fibula at an early stage, so as to get the tibial fragments together before sclerosis has occurred. The femur is rarely the seat of an ununited fracture due to a loss of substance, because the strong contraction of the thigh muscles brings the bone ends together, and if the loss is not more than $1\frac{1}{2}$ in., and if care be taken to secure correct alinement, I think that this natural mode of cure should be encouraged.

2. **Gross Displacement as a Cause of Non-union.** In 35 per cent of the cases, non-union is due to displacement of the main fragments. Such displacement may bring about non-union in a variety of ways, e.g. the interposition of muscle and tendons ; the wrapping round of the raw bone end in periosteum or fascia ; or the placing of a wide interval between the fragments, which becomes filled with dense scar tissue. Non-union of fractures, results from displacement, for the same reason that it does from loss of substance—that is to say, in each case the wounded bone surfaces are removed too far from one another for a callus bridge to occur between them. It is much less likely to result from displacement than from loss of substance, because the most frequent form of displacement is an overlapping, in which broad contact between the fragments is retained. In other words, if alinement is maintained, union will occur, even if there is shortening ; but if there is marked angulation, then the bone fragments become separated by the intervention of soft tissues, and callus bridging is prevented.

The femur affords the most important example of a bone which is liable to non-union from displacement. Such displacement is brought about by the traction of the great muscles of the hip and thigh. It is easily overlooked because being in the antero-posterior plane it is not revealed by an X-ray taken from before backwards, and it is often unaccompanied by much shortening in the early stages. Only lateral or stereoscopic X-ray pictures and an appreciation of the natural pull of the muscles will lead to its detection. It occurs in any part of the femur, but particularly in the upper and lower thirds. In the upper third it is due to the proximal fragment being tilted forwards by the ilio-psoas muscle, the main shaft lying behind. In the middle third it is due to a sagging backwards of both fragments, with an intervention between them of the muscle fibres arising from the linear aspera. In the lower third the displacement consists in a flexion of the distal fragment at the knee, brought about by the contraction of the gastrocnemius muscle.

All these varieties of displacement non-union are due to incorrect

or inefficient extension having been applied in the early treatment of the case.

I do not deny that they can often be prevented in the use of a straight splint, such as a Thomas, by special care being taken to bring about

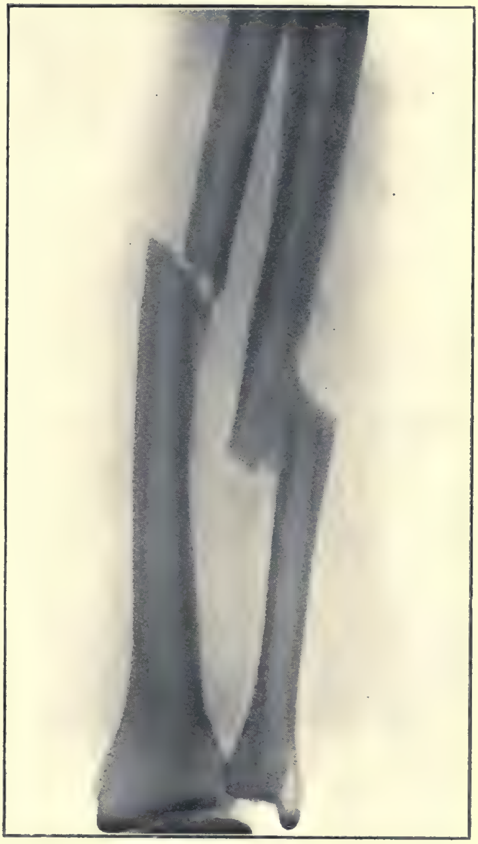


FIG 45.—Radius and ulna of *Case* 26 before operation.

FIG. 45 A.—Radius and ulna of *Case* 26 immediately after plating.

over-extension and particularly by slinging the leg in such a splint, so that backwards sagging of the fragment distal to the fracture is prevented. But, on the other hand, I am fully convinced that the natural and easy method of preventing them is to treat the leg throughout, in a position of natural physiological rest, in which the hip is flexed and abducted and the knee-joint flexed. This position naturally brings the shaft of the bone into line with the forwardly tilted upper fragment or the back-

wardly tilted lower fragment. Then if in this position efficient pin extension be adopted, full length as well as alinement will be attained, and under these conditions I have never seen the occurrence of non-union of the femur.

I might mention, in passing, that this transfixion extension is best carried out in the following manner. The *tibia* is transfixed just behind and below the tubercle by a pin 4 in. long and $\frac{1}{8}$ in. thick. The leg, in

FIG. 45 B.—Radius and ulna of *Case* 26 three months later, showing non-union of fracture and pulling out of screws.

FIG. 45 C.—Same case three months after double-step cut operation.

the position of flexion of thigh and knee, is then slung either to a Balkan splint, Hodgen, or wire-cradle, and extension of about 20 lb. applied. Counter-extension is made by a padded perineal band applied round the sound thigh, and this, by tilting the pelvis up on the sound side, assures abduction of the fractured femur. The great advantage of the tibial site of transfixion is that it concerns dense avascular bone, and not the soft cancellous bone of the lower end of the femur. The pin can be left in place for two or three months, where it remains quite firmly. If the transfixion site becomes a septic seton track, it is so superficial that it is easily treated, and it does not lead into connective-tissue planes like those of the thigh. As the main object of extension of the thigh in

fractured femurs is to overcome the contraction of the quadriceps and hamstrings, and as the insertion of these is into the heads of the tibia and fibula, the tibial transfixion site is well calculated to act with maximum result upon these muscles.

I am glad to learn from all published accounts that suspension, weight extension, and the flexed position of the joints have now been generally

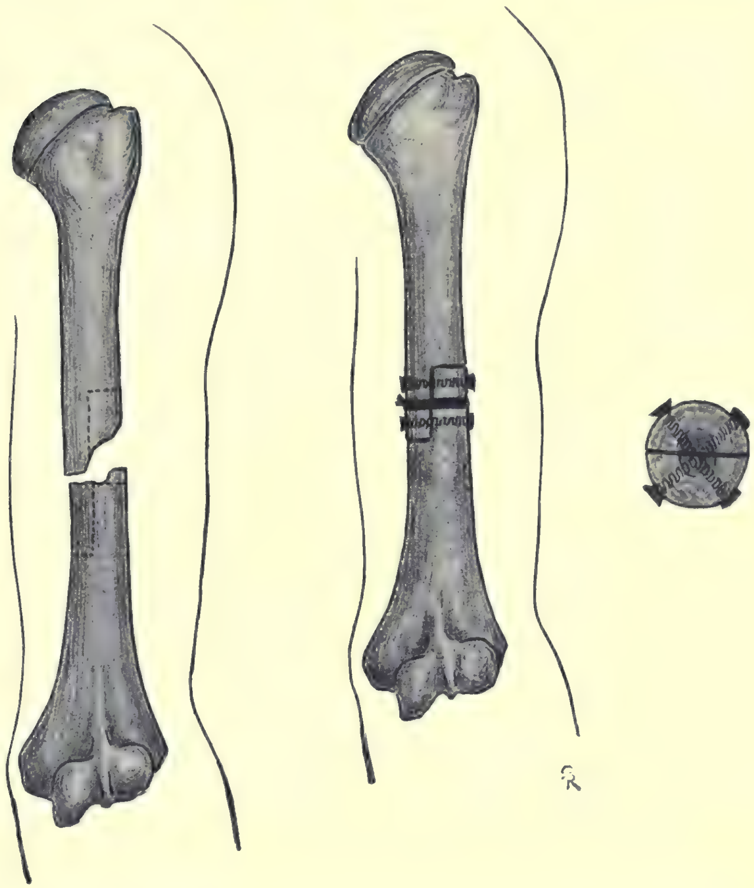


FIG. 46.—Diagram of step cut operation for ununited humerus.

adopted in the Service ; but unfortunately many cases are still put up in the straight position, and merely tied to a splint, and I cannot urge too strongly that this involves a great danger of uncorrected displacement and non-union, especially in fractures of the upper and lower ends of the femur.

Apart from these injuries of the femur, there is one other type of fracture in which displacement commonly leads to non-union, and that

is in lesions of the shaft of the radius, where the distal fragment is pulled inwards and is liable to become attached to the shaft of the ulna. Such a case will usually require a reconstructive operation eventually; and whilst primary healing is occurring, all that can be done is to maintain supination of the forearm with adduction of the hand.

3. **Non-union due to Necrosis.** I have been surprised to find, in the vast number of septic fractures, that necrosis of the main fragments seldom leads to non-union, probably in not more than about 5 per cent. The ends of the main fragments may be septic, but in the natural course of healing they are eliminated by a process of molecular absorption much more frequently than by that of necrosis. It is true that this delays union of the fractures, but such a delay is quite a different thing from the occurrence of non-union. For while the damaged ends of the bone are being reconstructed by granulation tissue, there usually occurs an outpouring of bone cells which make for repair and eventually bring it about. It is quite unusual, in my experience, for the ends of the main fragments of a septic fracture to undergo total necrosis, a reason for this being that, apart from ill-judged operative interference, such bone fragments retain a good blood supply and are able therefore to take care of themselves.

The deduction from this argument is one of great importance, viz. that it is unwise to attempt to bring about the healing of a septic fracture by cutting off the ends of the fragments. In any given case where union is much delayed, it is always worth while to open up a septic fracture and to remove obvious sequestra, but the main fragments should be left alone, because their removal usually takes away important elements of repair. We often get cases in which the ends of the main fragments have been sawn off, with the idea, no doubt, of removing infected tissue. But as these bones can take care of themselves, and in the process of throwing off infection also throw out reparative callus, it would seem to be a strong reason for leaving them alone. It seems to me bad surgery to remove any attached fragment from a comminuted fracture; but it is still worse to cut off the ends of the main fragments.

4. **Eburnation as a Cause of Non-union.** This is so well known as a complication of plating operations that it has been made the basis of the suggestion that all such procedures should be replaced by the sliding-graft operation devised by Albee. I will return to this matter later on in another connexion, and in the meantime it is enough to emphasize the fact that operative treatment of fractures may, under certain conditions, be an actual cause of non-union. The ends of the bone are exposed and partly deprived of their vascular supply by separating them from the soft tissues (Figs. 45, 45 A, B, C). Then they are fixed to an internal splint, which does not necessarily press the raw surfaces together, but, on the

contrary, often holds them apart. The bones, being deprived of the natural stimulus of contact and friction, and having their blood supply diminished, do not throw out callus in normal amount. Then, when muscular strain is allowed to fall upon the bone, its effect is to loosen the screws in one fragment or the other, and this usually occurs before the delayed callus union has been effected. At this period the bone ends are indolent and

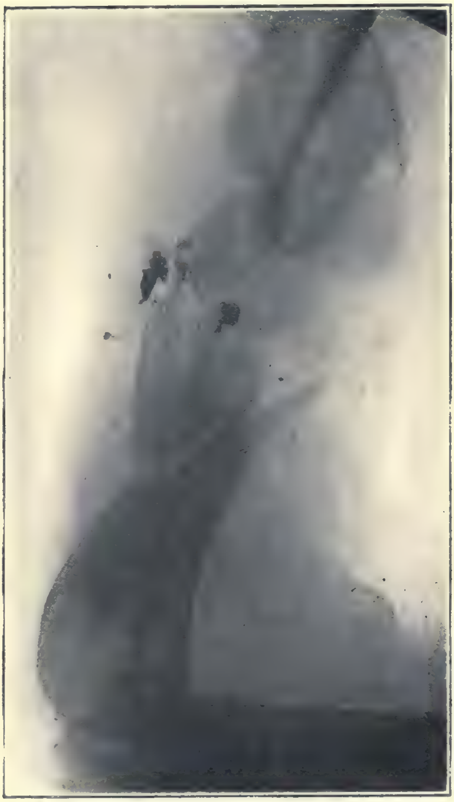


FIG. 47.—Humerus of *Case* 36 before operation. Note the comminution and atrophy of the bone at seat of fracture.

FIG. 47 A.—The same bone after step-cut operation, fixed between two aluminium bolted plates. Perfect result.

eburnated, and non-union is the result. I do not suggest that this is the usual result of plating operations, but it is a sufficiently common one to be a matter of importance. It is likely to occur in proportion to the conditions which favour slowness of callus union. That is to say, it is probable in feeble conditions of vitality and of circulation, in those situations where there is a constant muscular strain tending to angulation, and, above all, when plating is done at a long period after the original injury, when eburnation of the bones has already set in. If I am correct in these

statements, then it would follow that plating of the ordinary kind is especially unsuited for the treatment of ununited fractures.

The Influence of Sepsis and Mobility. It will be noted that I have not included either sepsis or mobility among the causes of non-union of fractures. This is for the reason that, after the most careful consideration, I cannot find evidence of either of these conditions acting in this manner.

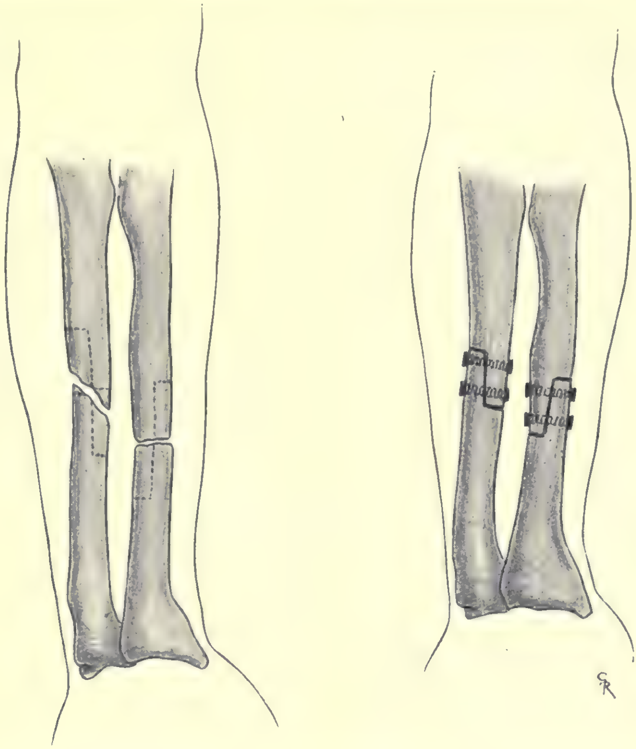


FIG. 48.—Diagram of step-cut operation for radius and ulna.

Of course, a fracture will not unite whilst acute infective inflammation is in progress ; but when this has been checked by drainage and the natural processes of tissue resistance, then the mere persistence of a local sepsis does not cause non-union of the fracture. The more quickly and the more thoroughly sepsis is removed, the quicker and better will be union of the bones. But late union of the bones does occur in the presence of sepsis, and is, indeed, simply a part of the phenomenon of union by granulation tissue.

Neither is mobility of a restricted type a cause of non-union. By restricted, I mean mobility which does not dislocate the ends of the bone from contact with one another. I lately had a remarkable illustration of the way in which mobility actually encourages rapid union. A flying

officer sustained a fracture of the base of his skull and a fracture of both femurs. He was put up in two cradle splints with weight extension applied by tibial transfixion ; but for more than four weeks he was very delirious and restless, and in spite of sedatives he moved his legs incessantly, so that the two weights were pulled up and down on their pulleys with the most menacing regularity. Fortunately his mind made

FIG. 49.—Humerus of *Case* 35 before operation.

FIG. 49 A.—Same bone successfully united by step-cut operation.

a rapid recovery, and the femurs united firmly in six weeks, whilst he was able to walk in eight weeks, and play tennis in four months (Figs. 42 and 42 A). Similarly, I find in all fractured femurs that movements of the knee and hip carried out from the third week onwards, with massage, greatly hasten and assure good union. This can be carried out, when the limb is slung in a semiflexed position and alinement maintained by weight extension, in a way which no other method that I know of, allows

One more point may be mentioned in this connexion. If an excision of an ankylosed joint is performed, then ultimate mobility—i.e. non-union—will be best secured by absolute rest for several weeks, followed by only the gentlest movements. On the other hand, if anything like forcible (i.e. painful) movements be undertaken at an early stage, then re-ankylosis will probably occur. This is only another illustration of the fact that restricted mobility causes rather than prevents bone growth, whether in the shaft of a bone or at its joint extremities.

The Natural Course of Ununited Fractures. It is of some importance to inquire what would be the result of leaving ununited fractures to the course of nature. If the ends of the bone are separated by a considerable distance, either from loss of substance or by displacement, it is almost certain that union will never occur. This for two reasons: first, that new bone is not laid down in adult tissue except as a thin layer covering the bone wounds; and second, that these wounded bone surfaces soon become wrapped round in a dense avascular connective-tissue envelope which seals up the little osteogenic impulse which first existed. It must be admitted, however, that it is extremely difficult to be certain about the behaviour of the bone in any given case, so that it is always wise to wait for a long time before deciding that union is not going to occur by natural means. During this waiting period the various well-known methods of stimulating osteogenesis may be tried. These are—in their order of usefulness—movement, passive congestion, percussion, and injection of various fluids. In my own experience, the first three of these methods will almost invariably succeed in producing union in all cases where there is actual bone contact between the main fragments, supposing that their application has not been too long delayed. They are quite useless, however, in regard to osteogenesis when there is a large gap between the bone ends, though they do something to preserve vascularity and function.

In all doubtful cases, i.e. where the separation of the bone fragments is definite but small, then decision between expectant and operative treatment must depend upon the amount of deformity which will result from the former, and the prospect of correcting it by the latter. So long as infection or its results have to be got rid of, and there is definite evidence of recovery of continuity by the bone and of function by the muscles, then the time of waiting is all a gain. On the other hand, if there is no continuity restored in the bone (and this applies especially to single bones, e.g. the humerus or the femur), then prolonged waiting does definite harm. This is due to two circumstances: first, the bone itself undergoes changes which are prejudicial to a reconstructive operation; the fragments always suffer from atrophy or sclerosis, and in each case this involves a diminution both of vascular supply and of bone-forming cells. Secondly,

the soft tissues all suffer from the loss of their normal skeletal support; the muscles waste and lose their function, and the nerves are often so dragged upon as to be incapable of conduction.

Therefore, whilst I advise waiting where there is prospect of natural

FIG. 50.—Humerus of *Case* 33 after step-cut operation.

FIG. 50 A.—Same bone two weeks later, showing the breaking away of the step from the upper fragment. This would have been avoided by the addition of a plate as in *Case* 36, Fig. 47 A.

recovery, I would deprecate this in other cases where there is great loss of function, deformity, and no prospect of callus union.

II. NON-OPERATIVE METHODS OF TREATMENT

I have already mentioned those means of hastening the union of indolent fractures which are of most service. They are passive congestion, percussion massage, and movements both passive and active. But I do not think that any of these methods are of much avail in genuine

cases of non-union—that is to say, in those where the bone ends are separated by dense scar tissue or by soft tissues. Such methods ought to be applied comparatively early in the course of any given case, at a time when cellular proliferation is still a potential factor, and before all bone canals are superficially closed and all intermediate tissue is converted into dense scar. They ought to be regarded rather as methods of prevention of non-union than of cure.

FIG. 51.—Humerus of *Case* 34, united over a short ivory peg with successful result.

FIG. 52.—Femur of *Case* 49 successfully united over an ivory peg.

Passive congestion is a method of the greatest possible value in expediting the healing of a fracture. It may be applied in two ways: either by tying a piece of drainage tube above and below the seat of fracture (Thomas); or by the use of a flat rubber bandage applied above the injured portion of the limb (Bier). Each method has its own advantages. Thomas's method produces a more local congestion, but in the forearm and below the knee it has the drawback of tending to displace the parallel bones towards one another. Bier's method produces a more massive congestion, but requires more skill and judgement in its application. It is

especially suitable for the forearm or leg bones, and for any case with extensive wounds.

Another method which acts by encouraging local congestion is the application of a light plaster-of-Paris bandage, provided with a window opposite the wound. This should be applied with the limb raised, and when it has set, the limb is lowered and used. Local œdema of the parts at the window is produced, with a temporary increase of discharge. The limb can be used, and this promotes the circulation and also some frictional stimulation of the bone ends.

Deep and percussion massage should be used in all cases where mobility at the seat of fracture persists unduly. The presence of pain during manipulation is a useful guide in this matter. In the early stages of normal fracture recovery, any attempt to move the bone is accompanied by pain, and such should, in my opinion, be most carefully avoided. Later on, however, if the fracture has assumed an indolent condition, manipulation is painless; and this is an indication that deep massages and even friction of the bone ends together, should be carried out.

The rôle of *movements* in the treatment of fractures has been emphasized quite rightly by Lucas-Championnière. But movements must be regulated by two conditions: they must be painless, and must not tend to displace the fragments from one another or to alter the alinement of the bone. Passive and active movements, most carefully adjusted for each case, should be carried out as soon as these can be done without causing pain or moving the fragments. Then, when a fair degree of consolidation has occurred, a suitable case splint is applied and purposive functional movements encouraged. I have never seen a case of the non-union of a fracture which could be attributed to such movements, but I have seen many in which delayed union was due to the opposite condition, i. e. to rigid immobility. The great danger of early mobilization of fractures lies in the liability of the bending of soft callus union, and this must be recognized and prevented by suitable splinting or posture.

There are four situations in which this danger should always be guarded against: (1) in the upper end of the humerus, the bone becomes angulated outwards, and this can be prevented by keeping the arm in an abduction frame. (2) In the radius, there is always a tendency to pronation, which must be prevented by a supination splint taking its bearing above the elbow-joint. (3) At the upper end of the femur, there is a tendency to angulation outwards, and this often persists in gunshot fractures for twelve months after the original injury. It must be fully corrected in the first place by efficient extension in a position of flexion and abduction of the thigh, and then maintained, by some form of rigid metal splint such as the walking calliper. (4) There is a tendency to a backward sagging of the middle of the femur in fractures of the shaft of that bone.

This, again, must be first corrected by suitable cradling combined with extension, and then maintained by a light case splint suitably supported to the opposite shoulder.

Operative Measures which aim at Callus Production without Suture of the Bone. There have been many proposals to attempt callus stimulation without bone suture. They consist in needling the bone ends, injection of blood or of fibrin, the insertion of magnesium, or the drilling of the fragments. No doubt all these have a certain value ; but from a practical standpoint in dealing with really ununited fractures they are unsatisfactory. Based upon experimental evidence, they are liable to fail, for the conditions of an ununited fracture are different from those which obtain in experimental conditions ; that is to say, there exists a sclerosis both of the bone and soft parts in ununited fractures which is not present in animal experiments. Clinically, therefore, these methods either do too much or too little ; they are superfluous or they are futile. If sclerosis of the tissues is not present, then the methods of congestion, deep massage, and limited movement will suffice ; if it does exist, and if an open operation is necessary, then something more certainly efficacious is indicated. Multiple drilling of the bone fragments after removal of the scar tissue is certainly the best of these callus-stimulating devices ; but it will only succeed where there has been no loss of bone substance and no gap to be filled.

III. CONSIDERATIONS PRELIMINARY TO OPERATIVE TREATMENT

In every case of ununited fracture there is one of three principal causative factors—either a gap in the bone, an interposition of soft parts, or an indolence of the bone ends. The last-named factor is one of great importance, because it arises in every case sooner or later, whether it is a primary condition or not. It may actually arise from the other two conditions—namely, want of continuity or the interposition of soft parts—or it may be caused by septic inflammation, which brings about a filling up of the vascular canals of the bone and a covering of its surface with scar tissue. Indolence of the ends of a fractured bone may take the form either of atrophy or sclerosis. Atrophy is most conspicuous when there is a gap in the continuity of the bone, sclerosis when there has been marked septic inflammation. But in either case the condition of the bone ends with which it is desired to bring about union is very unsatisfactory. Either there is a shaft of a bone which consists of a mere thin shell filled with fatty marrow, or else there is a dense avascular substance which is best described as bone scar tissue. Such bones will not throw out callus in the normal way however they are treated, and all

the non-operative methods of treatment are therefore likely to fail. Similarly, other methods which merely aim at suture of the bone, without providing for the removal and replacement of this unhealthy tissue, will also fail, and this must be one of the cardinal facts to be borne in mind in the consideration of all operative procedures.

Before describing and discussing the various operative methods which are available for ununited fractures, it will be necessary to consider various conditions of the tissues which exist, especially in cases of gunshot injury, together with some general technical principles. Upon a correct appreciation of these conditions and principles will depend the choice of cases for operation, the determination of the best period for operation, the selection of the type of operation, and finally, in a large measure, the success or failure of the operative treatment. These various factors may be summarized as follows: (1) *latent sepsis*; (2) *scar tissue* (skin, soft tissues, bone); (3) *vascularity*; (4) *functional conditions of muscles, nerves, and joints*; (5) *aseptic technique*; (6) *immobilization.*

1. **Latent Sepsis.** It would be out of place here to enter into the very difficult problem of septic infections of wounds and the possibilities of their sterilization and suture. But it is necessary to emphasize most strongly certain facts which have been repeatedly urged, and which, though difficult to understand, nevertheless lead to plain conclusions.

Whatever may be the possibility of sterilizing wounds of the soft parts and of the bones in the early stages of their existence, this possibility has vanished at a late period. From this it follows: (1) that the most important problem of military surgery still consists in an early and thorough treatment of the wounds so as to allow of primary or delayed primary suture; and (2) that if this has not been done, then a very long interval must be allowed to elapse before reconstruction operations are undertaken, in order that natural processes of reaction against infective organisms may be complete. We have long been familiar with the idea of latent infection, particularly in the case of tuberculosis. We knew that the so-called cure of a tuberculous disease was often only a comparative term, and that any violent trauma such as that entailed by wrenching a tuberculous joint would almost certainly lead to a violent recrudescence of the infective disease. Just so it is with limbs which have for weeks or months been subject to pyogenic infection. In proportion, probably, to the length of time that infection is known to have existed, will be the period necessary for the infective agent to be eliminated, even after the outward signs of infection—i.e. inflammation or an unhealed sinus—have disappeared. The probability of latent infection and the length of its duration in any given case is in proportion to: (1) the extent of the primary wound and its degree of infection; (2) the amount of scar tissue deposited in the tissues; (3) the length of time during which

manifest infection is known to have been present ; (4) the extent of bone involvement. This latent infection will be slight and transient in a clean through-and-through wound which has quickly healed, and it will be great and of long duration in an open lacerated wound which has slowly healed with a deposit of much scar tissue ; and of all wounds, those

FIG. 53.—Femur of *Case* 58, ununited after sixteen months. Note the atrophy of the bones.

FIG. 53 A.—The same bone united over a long steel strut introduced from the tip of the great trochanter.

which have opened up and comminuted large tracts of bone tissue will be those which harbour latent sepsis the longest.

It has been generally accepted that a period of three months should elapse between the healing of a septic wound and the undertaking of any reconstructive operation. This may be a good working rule, but I think should be regarded as a minimum, to be increased when there has been a large wound, much scar tissue, and much bone involvement.

Case.—A fracture of the lower end of the femur, in which the distal fragment was tilted backwards almost at right angles. The patient suffered much pain owing to the pressure of this fragment upon the popliteal nerves and vessels. He had two clean granulating wounds, and a febrile temperature. It was three months since the date of his wound. Through two lateral incisions I restored the alinement of the bone, and fixed it by double bolted plates. The operation was very difficult owing to adhesion between the lower bone fragment and the vessels in the ham, the separation of which caused great bleeding. He developed septic moist gangrene of the foot, and after amputation at the fracture had been performed, tetanus supervened, from which he only recovered after a desperate struggle.

Fig. 54.—Femur of *Case* 57 after five months' treatment on a Thomas splint. The upper fragment was tilted forwards and there was neither contact nor union.

When the wounds have soundly healed, it is not enough to wait passively for three or four or six months; but during this time active and passive congestion must be encouraged by heat, deep massage, and intermittent bandaging with rubber tubes. The functions of the nerves, muscles, and joints must be retained as far as possible by electrical stimulation and, above all, by purposive movements.

2. **Scar Tissue.** Second only in importance to autogenous infection by latent sepsis, as a cause of failure, is the presence of large masses of scar tissue on the surface and in the depths of the wound. Probably the infective agents become encapsuled in the scar tissue, just as happens in the healed tuberculous foci of a phthisical lung. Not only is scar tissue resulting from a septic wound to be regarded as a germ envelope, but also it is a tissue of very low resistance to extraneous infection. The most striking evidence of this is afforded by the behaviour of cutaneous scars after operation. The wound heals by first intention, but if a large skin scar has been left to cover the tissues, then within a few days this gives way in part or altogether melts away, leaving a superficial ulcer. But after all the skin is only the visible aspect of the scar, and the deep

scar in the soft tissues and the bone—whether at the ends of the main fragments or as isolated pieces—must also be regarded as tissue of poor vitality, deficient circulation, and weak resistance. The ideal principle to be arrived at is to remove all this scar tissue before attempting to reconstruct the bone. In practice it is usually the best plan to do one

FIG. 54 A.—The same bone as Fig. 54, united over a long steel tube, which was left in place for eight weeks.

FIG. 54 B.—The same bone firmly united after removal of the tube.

or more preliminary operations for the substitution of the skin cicatrix and the soft-tissue scars. It is best in the case of a large skin wound to take a pedicled flap from the chest (in case of the arm) or from the opposite leg (in case of the lower member), and to cut the pedicle in from seven to ten days. The deep scar is removed at the same time, as far as possible in one mass, the surrounding muscles being then brought together to obliterate the dead space. This secures a thick fatty skin-

covering for the site of the future bone operation. It is better to leave the removal of bone scar—i.e. the ends of the main fragments—until the actual reconstructive operation is to be performed; but loose bits of bone should be taken out with the fibrous scar tissue in the preliminary operation, on the two grounds that they are often the seat of latent

FIG. 55.—Femur of *Case* 60, three months after accident.

FIG. 55 A.—Same bone united over a 6 in. by $\frac{1}{2}$ in. ivory peg. The wound healed and the fracture united.

infection, and that, being quite indolent and avascular themselves, they only tend to prevent vascularization and bone growth at the site of the reconstructed bone.

3, 4. **The Functional Conditions of the Muscles, Nerves, and Joints, including the Activity of the Circulation.** It happens only too often that, after a long period of waiting for sinuses to heal and for latent sepsis to disappear, the general nutrition of the limb has suffered and the muscles atrophied to such an extent that a very poor prospect is offered for bone repair. Under such circumstances it is very doubtful whether it is justifiable to operate, and the question arises whether nutrition and

function can be restored before repairing the bone. Two kinds of treatment must be patiently pursued. On the one hand, the nutrition must be maintained and adhesions of the tendons and joints prevented by massage and electrical stimulation ; on the other, an apparatus must be provided which enables functional exercise of the muscles to be undertaken, whilst preventing deformity. In principle, such apparatus consists in making a light splint casing for the limb, with joints at the natural articulations ; being in reality the provision of a temporary exo-skeleton in place of the missing endo-skeleton. When the muscles have recovered sufficient strength under this treatment to move the limb, and when the blue, cold member has become warm and of a natural colour, then the bone repair may be done with good prospect of success. There is a great temptation to think that the bad nutrition and loss of function is best treated by first restoring the bone ; and as I have myself yielded to this temptation, I feel it the more incumbent upon me to state clearly that it should be resisted. In general terms, the longer the period of delay and the greater trouble taken preparatory to reconstruction of the bone, the greater is the chance of success.

5. **Aseptic Technique.** The general technique of aseptic surgery is so well known as to require no description here. Every proved source of infection and every reasonable suspicion should be guarded against, and this applies especially to the exclusion of the skin from contact with the operator's fingers and the instruments and ligatures. The most convenient means of carrying this out is by placing the limb in stockinget, the incisions being made through this material, the edges of which are then fastened to the skin by Michel's clips.

There are two procedures commonly recommended for bone surgery which appear to me to have no sufficient justification, but to be open to grave drawbacks. One of these is the dependence on forcipressure alone for hæmostasis. I think it is far better to ligate every bleeding point with fine catgut, for there is nothing more prejudicial to healing than the formation of a hæmatoma. The other is the dictum that the gloved fingers should not be put into the wound. If the hands are clothed with rubber and cotton gloves, I see no reason to doubt the sterility of these any more than that of the instruments or swabs. Moreover, complicated joinery cannot be well done without the help of the fingers. Accurate fitting and firm fixation are the two watchwords of operative bone repair, and for these, fingers are necessary.

6. **Immobilization.** The freshly united bone must be kept without disturbing strain until firm union has occurred. About this there can be no doubt ; the only question which has to be considered is how this immobility is best secured in such a way as to interfere as little as possible with the circulation of the part and attention to the wound. If the bone

repair has been done in a solid manner, then the actual fixation will be secured by this. On the other hand, if the parts, whether bone ends or bone grafts, have only been tied with soft ligatures, then reliance must be placed on plaster-of-Paris dressings. The application of these two methods of fixation will become apparent when the special operations have been considered.

IV. OPERATIONS FOR THE TREATMENT OF UNUNITED FRACTURES

These may be divided into the following categories: (1) *Plating;* (2) *Step-cut operations;* (3) *Intramedullary pegs;* (4) *Special methods;* (5) *Bone grafting.*

1. **Plating.** The usual operation of plating a fracture, practised upon a recent closed aseptic case, has certain drawbacks which I have dealt with elsewhere. These are briefly: (*a*) That the screws, holding only by a friction grip, are easily displaced and loosened by rarefication of bone. (*b*) That the screws, being all in one line, afford very inefficient mechanical fixation. (*c*) That if any tendency to displacement of the fracture persists, the plate becomes loosened from one fragment and allows angulation to occur. (*d*) That, in the case of a transverse fracture, a plate does not press the raw bone surfaces together, but on the contrary holds them apart.

All of these objections, which apply to recent clean fractures, are greatly increased in the case of old ununited and unhealthy bones. In the latter, fixation needs to be more secure and lasting, because natural union is so much slower and the rarefied or sclerotic bone affords a worse hold for screws than does a healthy one. To some extent the drawbacks may be overcome by using curved plates fixed by two rows of converging screws, by the use of bolts or pins which transfix the whole thickness of the bone, and by employing special plate clips which will be presently described. But even with these improvements, plating does not bring about close contact of bone surfaces, nor does it stimulate osteogenesis, but rather retards it. In the treatment of ununited fractures, therefore, plating alone must always be regarded as uncertain and unsatisfactory, and it should be reserved for special cases, or merely used as an internal splint for fixing the bone which has been united by some other method. When, however, a plate is used for an ununited fracture, it is very important to fix it in such a way that it cannot become loose.

In easily accessible bones, e.g. the humerus, forearm, and tibia, and in the lower end of the femur, much the most efficient method of fixing a plate is by the use of split pins or bolts and nuts which transfix the whole thickness of the bone. Split pins $\frac{3}{32}$ or $\frac{1}{8}$ in. thick are cheap, easily obtained, and easily manipulated in a situation—e.g. the forearm—

where both sides of the bone are accessible. The bolts I use are $\frac{1}{8}$ in. thick, and made of soft iron, so that the spare end can easily be cut off. In order to overcome the difficulty of pushing the bolt through from the deep side of the bone, I have devised a simple apparatus whereby a nut is fixed on to the deep end of the bolt and then the latter is fixed by a second nut on the surface of the plate. Fig. 43 shows a fractured femur fixed by a bolted plate.

FIG. 56.—Humerus in *Case* 31, the neck of the bone has been lost.

In most of the gunshot fractures in which bolted plates were used, the latter had ultimately to be removed on account of sinus formation; but in all except one case they had remained in place long enough to secure firm union in a good line,

Mere mechanical fixation of an unhealthy bone to a plate will not secure natural union. I have learned that it is wiser to be content in some cases with less perfect mechanical fixation, in order to simplify the operation and to have less exposure of the soft parts. This can be attained in the case of the femur either by using a curved plate with two rows of screws engaging the shaft in different radii, or by the use of the clips shown in Fig. 44A. An ordinary stout Lane plate is applied to the outer aspect of the femur with four screws. A clip is then placed on its upper and lower end, and fixed by two screws to each, these screws entering the bone at right angles to one another. This will prevent either end of the plate from being pulled away from the bone by the tension of the adductor muscles.

2. **The Step-cut Operation.** In the case of the humerus or both forearm bones, this is the best operation for ununited fracture, provided that there has not been much loss or bone atrophy of the bone ends. It involves an ultimate shortening of the bone to the extent of about $\frac{3}{4}$ in. to 1 in.

It is so simple as scarcely to require any description beyond that

conveyed by the illustrations (Figs. 45 to 49). The bone in question is exposed, all intermediate scar tissue is removed, and the fragments are cut off square. Half the thickness of each fragment is now cut out from opposite sides in the shape of a step about ¾ in. long. The socket in each bone end is then shaped with a square file so as to fit the other accurately. Having been fitted, the bone is held by a clamp forceps, two ⅛-in. holes are drilled through both flanges in slightly different directions, and the ends are fixed by split pins or bolts. One case is so instructive in relation to operative bone repair that I will relate it here.

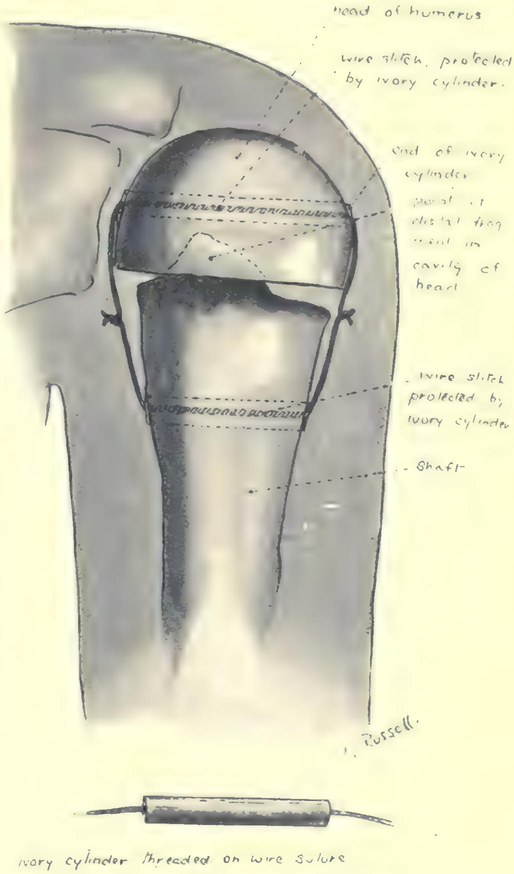


Fig. 56 a.—Diagram of operation in *Case* 31. The wire sutures are protected from cutting out of the soft bone by being encased in ivory tubes. Successful result.

Case Lt. C. sustained a simple fracture of both bones of the forearm, March 21, 1917, by falling with his horse (Fig. 45). On March 23 both bones were plated in a Devonport hospital, and, as judged by X-rays and the perfect healing of the wound (Fig. 45 a), it could not have been better done. It was immobilized for six weeks, and then the splints daily taken off for massage for a further six weeks, when recovery was regarded as complete. Slowly, however, the forearm began to bend, until by November 21, eight months after the accident, he had a well-marked false joint, and came to the Bristol Orthopædic Centre for treatment. At this period the X-rays showed (Fig. 45 b) that each plate had become loose from one bone end, by the pulling out of the screws and loosening of their sockets. A double step-cut operation was done, each bone being united by two bolts. The wound healed well, and by March 3, 1918, his arm had become so strong that he was able to return to ordinary military duty (Fig. 45 c).

It will be noted in this case that though the plates were very perfectly applied within three days of the accident, yet they did not press the

raw bone surfaces together, but rather held them apart. Each bone fragment, therefore, healed without throwing out callus. When the splints were removed the bones were only held by plates and screws, and the latter quickly became pulled out from one end of each plate owing to the absorption of their sockets. This is a plain fact to be seen in the skiagram, and not a matter of conjecture. It cannot be attributed to sepsis or faulty technique, because the wound healed well and never showed any sign of irritation. On the other hand, the step-cut operation, by exposing and adapting fresh-cut bone surfaces and then closely pressing

FIG. 57.—Fracture of neck of femur, which had been ununited for five months, now fixed by a tibial bone peg.

these into apposition, conformed to the ordinary principles of the suture of wounds, and resulted in strong natural union.

The step-cut operation is not suitable for leg bones, because it involves a shortening of the limb, which is a matter of only secondary importance in the arm. It is not applicable for one forearm bone the fellow of which is intact. And lastly, it requires for success that the ends of main fragments which are fitted together shall be strong and healthy, subject neither to atrophy nor to that type of sclerosis which really converts the bone into scar tissue. This latter limitation is so important that I will illustrate it by reference to a case.

Case G. B.—A case of ununited humerus with much sepsis and loss of bone, associated with complete musculo-spiral paralysis. Here no

mistake was made in operating too soon; the patient was kept for nearly twelve months, and several preliminary operations were done for the cure of sepsis and the removal of scar tissue. At the operation a tongue of bone was found projecting downwards from the proximal fragment, and this was fitted into the lower part of the shaft and there fixed by two bolts (Fig. 50). At first he did well, and was so delighted at the new experience of solidity in his arm that he used it too freely. Re-fracture took place (Fig. 50 A), which is seen to be due to the tongue from the upper fragment having broken off. Disheartened by this, he asked for transfer to a hospital near his home, and I hear that at that institution amputation was performed.

It is clear from this case that if the integrity and soundness of the bone is in question, it is better to supplement the step-cut operation by a plate which takes off the strain from the actual bone ends. (Fig. 47 A.)

3. **Intramedullary Pegs.** *Short Pegs.*—The use of an intramedullary peg has very narrow limitations in the treatment of ununited fractures. It is only of use in the case of a perfectly clean and healthy bone, the fracture of which is recent, transverse, and uncomminuted, the cause of non-union being displacement with interposition of soft parts.

The pegs I use are turned from ivory or bone. They are $\frac{1}{8}$ to $\frac{1}{2}$ in. thick, and from 1 to 3 in. long. Each has an outstanding ring at its centre, which prevents the peg from slipping down into the cavity of the fragment in which it is first placed. A small incision is required for this operation, merely large enough to allow each fragment to be thrust out of the wound. The marrow cavity of each is opened and drilled until firm bone is reached (Figs. 51, 52). The peg is slipped into one fragment, and the other is brought over it by traction and angulation. Such a short peg will not serve to maintain the alinement of the bone, and this must be secured by suitable splinting until union has taken place.

Long Intramedullary Pegs for the Femur, introduced from the Trochanter.—In fractures of the upper end of the femur just below the trochanters, there are two difficulties in treatment. First, the proximal fragment tilts forward and outward, and unless the thigh is kept in abduction and flexion, no amount of traction will secure alinement. Secondly, when this deformity has been established for some time in the presence of sepsis, great atrophy of the upper portion of bone takes place.

In the treatment of such a fracture, whether one associated with non-union or mal-union, not only is considerable force necessary for correction of displacement, but continuous fixation by a powerful appliance of some sort is absolutely necessary in order to prevent recurrence. If this appliance is to be the external variety, it will involve many months in plaster of Paris; if it is a plate, then this must be fixed very differently from the manner which is generally employed. In fact, it is the study of any consecutive series of cases of this type treated by the usual Lane plate

that affords the most convincing demonstration of the fallacy of the orthodox technique. Plating is nevertheless applicable if a clip or other device be employed to prevent the upper and lower ends of the plate from being separated from the bone. But in that variety of case where sepsis has long held sway and the bone fragments are very atrophic,

FIG. 57 A.—The same bone a year later, showing complete absorption of peg and deposit of dense bone in its place. Perfect result.

the extensive exposure and multiple drilling necessary for plating is liable to re-awaken sepsis and to split the friable bone. It occurred to me therefore to use a long internal peg or strut, such as would render unnecessary any further fixation and would afford absolute rigidity. I have used pegs of various shapes, cylindrical, cross-sectioned, and solid rods, and I am inclined to think that the last named are the best, because they give the maximum strength, and there is an avoidance of hollows or crevices which form dead spaces. The technique of its introduction is as follows. (Figs. 53, 54, 55.)

The limb is subjected to transfixion extension for several days before operation. (If the method is used for mal-union and not for non-union, the junction must be divided by osteotomy before extension is applied.)

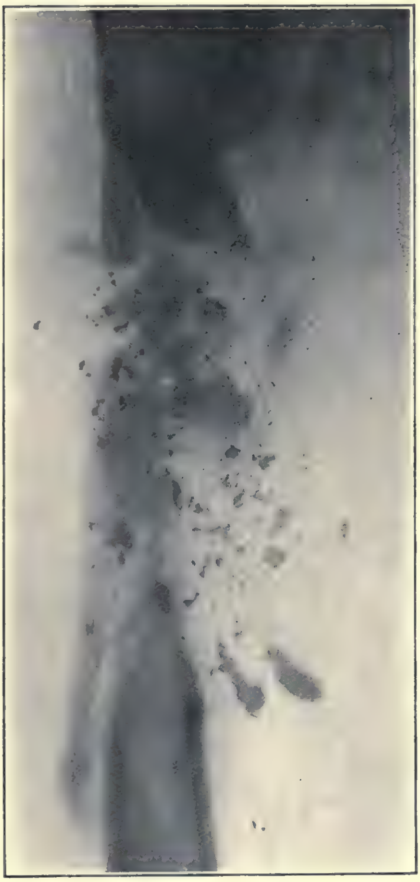


FIG. 58.—Femur from *Case* 55, seven months after injury. There was remarkable comminution, but in spite of the abundant metallic débris there was no sepsis, and the wound of entry was never discovered. There was union of the small fragments with the lower end of the shaft, but non-union between this mass and the proximal fragment, which was tilted forwards.

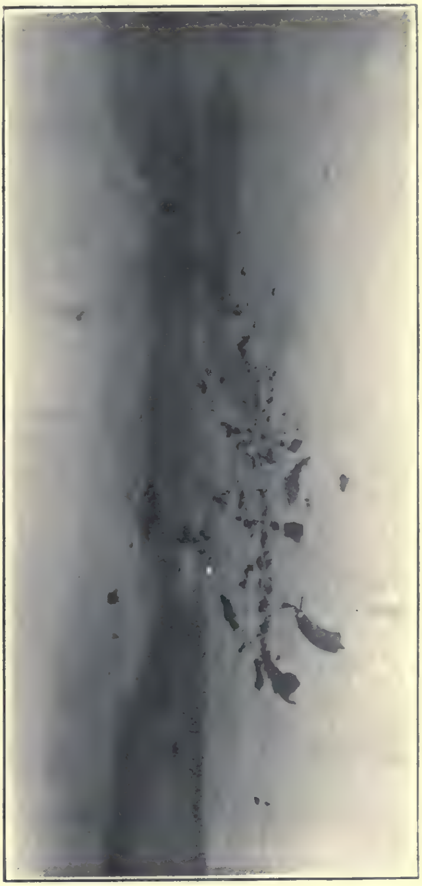


FIG. 58 A.—The same bone after the use of a long fibula graft. Photo taken one month after operation. Five months later he was able to walk with crutches and work a treadle fret-saw machine.

Then, when over-lapping and angulation have been corrected, the operation is performed. The seat of the fracture is exposed by an external incision, and each fragment is refreshed and drilled by a ½-in. drill. It will be

noticed that after piercing the conical end of the bone, the drill runs into the marrow cavity with the greatest ease, merely displacing a little fatty tissue. After preparing at least three or four inches of the distal fragment,

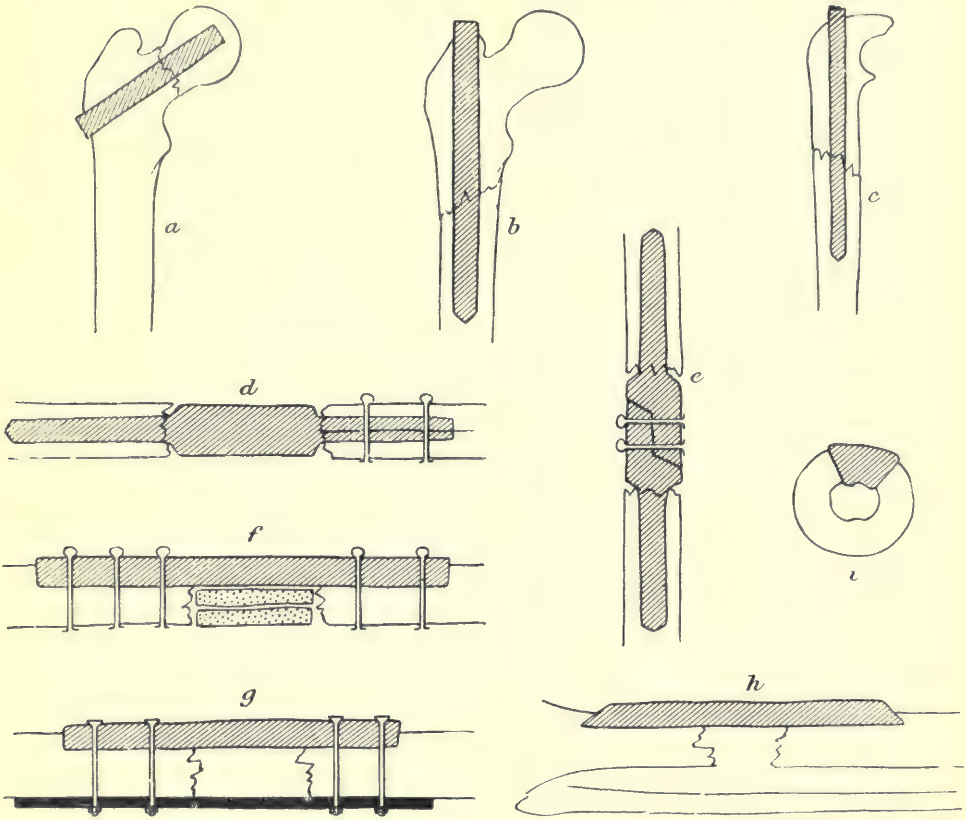


FIG. 59.—Showing methods of fixing and fitting a graft: (*a*) graft driven into trochanter, neck, and head of femur; (*b*) graft driven into medulla of upper third of femur from trochanter; (*c*) graft driven into medulla of proximal part of ulna from olecranon; (*d*) graft tightly fitted into both fragments of a fracture. At one end the shaft has been split for its reception, and then pinned together; (*e*) graft tightly fitted into both fragments of a fracture. The graft has been cut by a fret-saw in a Z manner and pinned together afterwards; (*f*) graft fitted as a cortical strut and fixed by pins. The fragments marked by dots have been cut from the shaft and used to fill up the gap between the main ends of the bone; (*g*) graft fitted as a cortical strut and bolted to a plate on the opposite side of the bone; (*h*) inlay graft fitted and fixed without metallic sutures; (*i*) section of the inlay graft showing its wedge shape.

the proximal one is drilled by a special drill 12 in. long. This is driven right up through the great trochanter, the tip of which is exactly in a line with the axis of the femur. The tip of the drill is made to emerge against

the skin of the buttock and then cut down upon. The drill is removed, and the peg (6 to 9 in. long) is then pushed up the proximal fragment until its upper end emerges from the buttock wound and its lower is left projecting about half an inch from the bone end. The two fragments are now brought into apposition and into line, and the peg is hammered down until it engages the lower fragment by several inches. The length

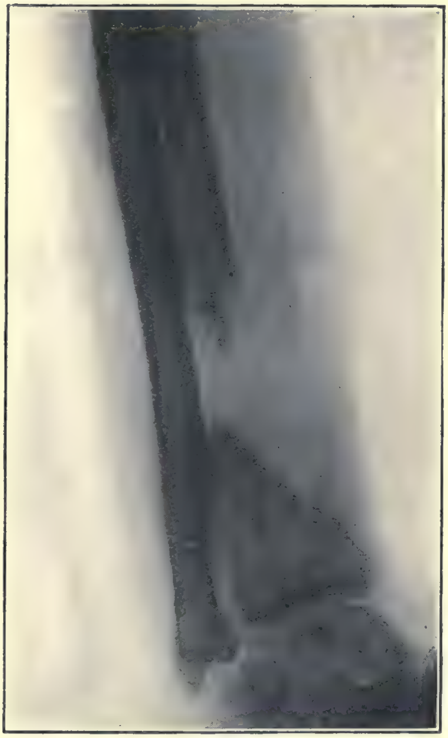


FIG. 60.—Radius from *Case* 2, with characteristic displacement.

FIG. 60 A.—Same case after operation by tibial graft. It failed, and illustrates well the causes of failure. There is insufficient contact between the graft and its bone bed, and what contact there is concerns unhealthy atrophied bone.

of the peg ought first to be determined by the position of the fracture, so that when it is in position, with at least three inches in the distal fragment, its upper end shall remain projecting from the top of the great trochanter. This is to allow for its removal at any time if necessary.

4. **Special Methods of Operation of Occasional Value.** In certain cases no classical method of bone repair can be adopted, and special devices may be employed. Such are illustrated by the following cases.

Case 31.—Loss of bone just below the head of the humerus (Figs. 56, 56 A). After very long preliminary treatment and the removal of sequestra, the wound healed. Then the following operation was performed. The seat of fracture was exposed, and the lower fragment, shaped in a conical

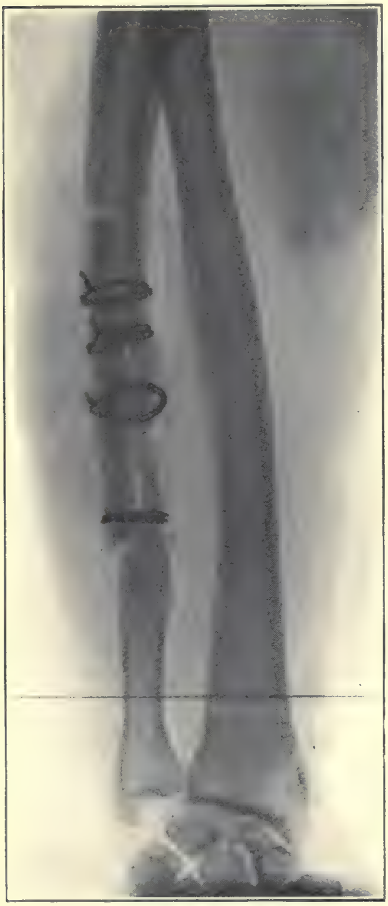


FIG. 61.—Ulna from *Case* 15, treated by a naked tibial graft fixed by encircling wire. The gap between the bone ends has been filled by the bits cut out for reception of the graft. Complete success.

FIG. 62.—Humerus from *Case* 28 after the removal of the bone-graft. Illustrates the stimulation of new bone-formation by the graft. Firm union ultimately resulted.

fashion, was made to fit into a cavity in the head of the humerus. There was no room for any kind of plating, and a simple wire suture would certainly have cut out. Each fragment was drilled from side to side by a $\frac{3}{16}$-in. drill, and into each hole was passed an ivory tube carrying a $\frac{1}{16}$-in. iron wire. The ends of the wire were twisted together in the manner shown, after the fragments had been pressed into position.

Unfortunately the ends of the wire were cut too short at one side, and here eventually the junction gave way ; but nevertheless firm and good union took place, and the man has now quite a useful arm.

Case 25.—Loss of substance in the radius, associated with a gap in the flexor muscles over that bone. In this case I removed a piece of the ulna of sufficient length to allow of suture of the muscles, and the ends of the radius came together. The ulna was joined by a step-cut operation ; but although the muscles have united well, and are functioning, the bone has not united ; and if this continues for six months, I shall perform a bone-grafting union.

This type of operation, consisting in the removal of a segment of one bone in order to allow the falling together of its fellow, has, I think, a definite scope which is more important than is represented by the single case mentioned. It is applicable to certain fractures of the forearm and of the tibia. In the forearm, I should reserve it for those cases with a gap in the muscles as well as in the bone ; because if the former are intact, I think that bone grafting, after making good the scar, is the best treatment. In the case of a tibia with a small gap between the fragments, it is a good operation, because division of the fibula will allow the tibia to come together with a very little shortening (i.e. provided the gap is small), and this is a short and easy procedure compared with bone grafting.

V. BONE GRAFTING

The introduction of a living autogenous bone-graft is the main resource for the treatment of ununited fractures, and especially for those in which there has been definite loss of substance. Unfortunately, however, in the case of gunshot injuries there exist certain drawbacks and difficulties which make it much more difficult of success than when it is applied for the replacement of bone lost by disease—e.g. a tumour or tuberculosis. These, which have already been alluded to, are the existence of latent sepsis and the presence of extensive scars of skin, muscle, and bone.

I have recently (*British Journal of Surgery*, October 1917) summarized the historical account of bone grafting, and dealt fully with experimental evidence in relation to the subject, and I therefore confine myself in the present paper to clinical conditions, with special emphasis on this point, that the cardinal factors of latent sepsis, scar tissue, and deformities are features of the clinical problem not represented in experimental work.

Vital Conditions. These must be considered in relation to the bed and the graft. The essential condition to be obtained in the bed is the removal of scar tissue, whether cutaneous, fibrous, or osseous. Ragged bone ends must be removed, and no dependence placed upon them for osteogenesis or union.

The necessary vital conditions of the graft are more readily obtained, because this will always be taken from a healthy bone.

That a living autogenous graft continues to live in its new position when joined to living bone is no longer a matter of theory or microscopic investigation. It is proved by many facts, the most convincing of which is, that when a graft becomes fractured it produces callus just as does a living bone. This has been shown by many human cases and also by animal experiments.

FIG. 63.—Radius from *Case* 8 before operation. There was displacement and non-union.

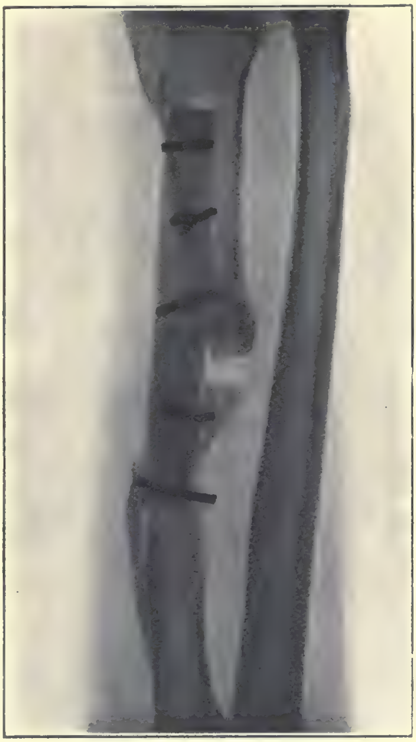


FIG. 63 A.—The same case after operation by tibial graft. The graft is fixed to each fragment by split pins.

That *the periosteum* is not an essential element in the graft is proved by the fact that in many cases a naked graft heals in position and becomes united to its bed (Fig. 61). The best example of this is in the living tibial peg driven into the neck of a fractured femur. Nevertheless, the preservation of the periosteum is very desirable in all cases except those where the graft is entirely intramedullary. There are two reasons for this. The most important is that the periosteum is the medium through which new blood-vessels most readily make connexion between the graft and its surroundings. It is the natural vascular envelope of the

bone which is ready to take up a new blood supply. Secondly, removal of the periosteum involves the removal of the very important superficial layers of osteoblasts, from which more bone growth takes place than anywhere else in the graft. Further, the preservation of the periosteum affords a ready method of suturing the graft in its place in those methods where no metallic sutures are employed.

FIG. 64.—Fractured forearm bones from *Case* 6. There is malunion of the ulna and non-union of the radius.

FIG. 64 A.—The same bones after operation. The ulna has been rectified by a step-cut operation, and the radius united by a long tibial graft, both fixations being effected by split pins. Complete success.

The rôle of the periosteum is remarkably demonstrated by the comparison of three types of operation :

1. Where a naked graft is used, increase in thickness of the graft, even after long survival, is very slow. Whenever sepsis supervenes, the graft becomes entirely exfoliated without depositing any new bone.

2. Where periosteal flaps with a thin layer of bone are turned down to bridge the gap, no new bone is deposited, and failure results. This shows that periosteum, even when retaining its attachment, will not deposit new bone in an adult.

3. Where a graft covered on one surface by its own periosteum is

used, its behaviour is different from either of the above groups. Increase in thickness occurs in all cases within a few months. In those cases where secondary sepsis supervenes, there is an abundant deposit of new bone between the periosteum and the graft. The solid portion of the graft may be exfoliated, but a mass of new bone is left behind of larger bulk than that originally used. In *Case* 5, Figs. 67, 67 A, for example,

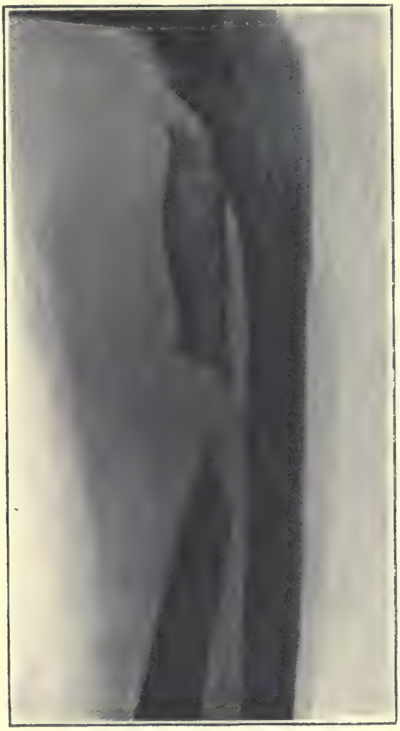


FIG. 65.—Fracture of the radius from *Case* 12.

FIG. 65 A.—The same bone after union by a graft. The upper end of the graft has been driven into the marrow cavity of the proximal fragment, and the lower end placed in the cavity of the distal fragment after splitting the bone. United by two pins. Complete success.

a periosteum-covered graft was bolted to the radius, to an aluminium plate on the opposite surface. Four months later a sinus persisted. There was massive new bone formation, and on removal of the plate and bolts ready healing took place, the gap being more than filled by new bone. In *Case* 6, two grafts were bolted to opposite surfaces of the incomplete radius, each having a periosteal covering on its outer side. A sinus developed and persisted. Five months later the wound was opened up. One graft had undergone a central necrosis, the rest being incorporated

with the living tissues. The other graft had almost entirely necrosed in its solid portion, but there was a mass of new bone forming an involucrum on its surface. There was firm and solid new bone filling the gap, although a large amount of the dense bone put in was lost.

Thus we have three facts : (1) naked grafts form new bone very slowly and scantily ; (2) periosteal flaps in adults form no new bone at all ; (3) bulky grafts covered by periosteum are capable of depositing thick new bone in the form of an involucrum. From these facts it may be inferred that the osteoblasts necessary for new bone formation are contained in the dense bone, but that the protecting and vascularizing matrix of the periosteum is necessary for their activity.

The best source of the graft has been much discussed, but for repair of the long bones I think that the crest or internal surface of the tibia holds most advantages. From this bone the greatest length and strength can be obtained with the minimum exposure or damage to soft parts. It is well provided with thick periosteum, and is readily accessible for accurate sawing. From the crest may be obtained a strong bone $\frac{3}{4}$ in. square in section, and from the surface a long thick plate $1\frac{1}{2}$ in. wide and $\frac{3}{8}$ in. thick. The only serious objection which can be urged against the use of the tibia is the fact that fracture sometimes occurs in it after the removal of a thick graft. This has happened in two of my cases, but in each it was only a small fissured fracture without displacement, and I do not regard it as of serious importance. The fibula has some points to recommend it. These are, that it presents a rod-shaped bone which requires no cutting, and that it is not an essential feature in the skeleton ; but it is very variable in its shape and size, and it is difficult to clear it of muscle without stripping it of its periosteum. With a proper motor saw, a good graft can be cut from the tibia much more quickly than from the fibula, in the case of a muscular leg.

In determining the size of the graft two points must be borne in mind. First, that no new bone of any mechanical importance can be expected to arise from it for many months, and that it must therefore be cut large enough to fill the gap it has to replace as far as possible. Secondly, that as the graft ought to have contact with a wide surface of bone bed on each side, it must be cut of sufficient length to secure this. The ideal length is not less than three times that of the gap. For example, if there is a gap of two inches between the main fragments after their unhealthy ends have been cut off, then the graft ought to be six inches long.

A further vital condition to be considered is that relating to the contact between the graft and its bed. Rapid and sound union will depend upon broad and accurate contact efficiently maintained, and it must be a main object of the technique to secure such contact. Just as bone gaps are filled very slowly or not at all, so any spaces between

the bone graft and its bed offer obstacles to bony union. Next to the importance of eliminating latent sepsis and scar tissue, nothing has impressed me more than the dependence of success in bone grafting upon this accurate contact. A reference to Figs. 60, 60 A, from one of

Fig. 66.—Forearm from *Case* 22. The ulna had been lost in childhood from osteomyelitis. He had nevertheless served as a soldier until he dislocated the head of the radius.

my earlier cases, will at once illustrate the type of union which is doomed to failure.

Mechanical Fixation. The success of all plastic surgery depends largely upon accurate suturing. Bone, being a tissue of slow growth and slow repair, requires more firm and lasting sutures than the soft tissues. There are three methods used for the fixation of a graft: (1) *Suture by ordinary absorbable ligatures*; (2) *Fitting by accurate joinery*; (3) *Fixation by means of metal screws, pins, wires, or plates.*

1. The first method, that of ordinary suture—i.e. of the periosteum of the graft to that of its bed—is only suitable for situations where there is no tendency to movement or displacement, e.g. in the repair of defects in the cranium; here, indeed, no sutures are really necessary. In the long bones, catgut or animal-tendon suture cannot be regarded as a serious method of fixation except for the attachment of the periosteum. If any strain has to be borne by ligatures in the fixation of a graft, then my own choice would be of some metal suture, e.g. a bolt or a pin; but failing such, I think it is better to use a piece of the patient's own fascia or tendon than to place any reliance upon catgut or animal tendons. In the leg, strands of the fascia lata, and in the arm a piece of the palmaris longus tendon, are far better suture materials than pieces of sheep's intestine or kangaroo tail.

2. The method of fixation always to be aimed at is that of fitting the graft into a slot or cavity in the bed in such a way as to require no suture at all. When this can be well done, the method in my experience never fails, provided latent sepsis has been eliminated and scar tissue removed. The simplest type of this fixation is seen in the use of a square tibia-peg driven into the cancellous tissue of the femoral neck for the fracture of that bone. *Case* 46 has been under observation for more than a year (Figs. 57, 57 A). Although he was discharged from the army by a medical board, who evidently were sceptical about reconstructive bone surgery, he has now such perfect function in walking and running that it is impossible to detect which is the injured leg.

In the same way, the living intramedullary peg can be used as a graft for the repair of fractures in certain situations, viz. the upper or proximal third of the femur or ulna. That is to say, in both these situations a peg can be firmly driven into the shaft of the bone so that graft and bed are firmly contacted in the whole length of the former. It must be carefully noted that this is a very different procedure from putting a living intramedullary peg into the site of a fracture, introducing it into one broken end and then bringing the other over it (as in the use of the short pegs described above). This latter procedure is by clinical and experimental evidence likely to fail, because the peg is so short and the fitting so loose. In the firmly-fitted living peg the shaft of the bone should be drilled much smaller than the peg, and the peg should not be round but angular in section. For example, in the femur the shaft is hollowed by a $\frac{3}{8}$-in. drill, which leaves a margin of at least $\frac{1}{8}$ in. of fairly soft bone all round the cavity. A square peg is cut from the tibia, 6 in. long and $\frac{5}{8}$ in. thick, and then filed down so as to pass through a $\frac{1}{2}$-in. hole. It then has a roughly octagonal section, and can be hammered into the $\frac{3}{8}$-in. hole so as to hold very firmly, and 3 in. will lie on each side of the line of fracture.

There are two other methods by which a graft can be firmly fitted as an intramedullary peg, and these are specially suited for cases where there has been a loss of substance (Fig. 59). Suppose that the gap to be filled is 2 in. after removal of unhealthy bone from the ends of the fragments; suppose that it is the radius to be repaired, having an outside

FIG. 66 A.—The same arm after insertion of a long tibial graft fixed above by two split pins.

diameter of half an inch and an inside cavity of a quarter of an inch. The graft is cut square and of 6 in. length. Each end is shaped with a file for 2 inches, until it fits tightly the holes drilled in the fragments. Into one fragment the graft is driven (temporarily wrapping the bone round with several turns of wire to prevent splitting). The other fragment is cut for $2\frac{1}{2}$ in. with a fret-saw, and the two halves are prized apart so as to take the spindle at the other end of the graft. Then this split end and the contained graft are sutured through two holes by suture or split

pins (Figs. 65, 65 A). In the alternative method, which is to be used if one fragment of the bed cannot be split as above described, the graft, having been shaped so as to fit at each end, is itself cut into two portions by a **Z**-shaped incision. Each half is hammered into place, and then the graft fitted together and sutured or pinned. (Fig. 59 *e*.)

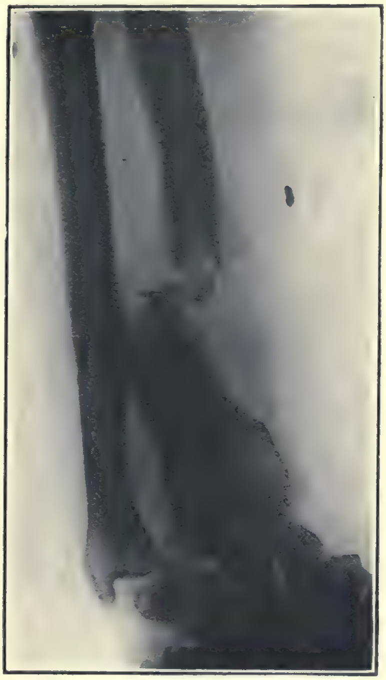


FIG. 67.—Radius from *Case* 5.

FIG. 67 A.—The same after operation. The bone has been united between a tibial graft and an aluminium plate by four bolts.

The inlay cortical graft, which has been used and popularized by Albee, is a superficial graft, laid down in a slot cut for it in the cortex of the bone to be mended. Albee uses a twin saw, but if the same twin saw be used to cut the graft and the slot into which it is to fit, then the latter will be too large by two saw thicknesses, and for strong work I think it is better to make a shelving trough, cutting each side separately with a simple saw-cut. Then the graft can be hammered down into its bed, the hollow bone having enough elasticity to open a little for its reception. The ends of the graft should be bevelled so as to underlie the ends of the

slot. Thus the muscular tension will prevent the graft from slipping out (Fig. 69).

In some cases one end of the graft may be shaped as a peg and driven into the marrow cavity, while the other end is recessed into a flat cut on the other fragment and there secured by pins (Figs. 68, 68 A).

FIG. 68.—Forearm bones from *Case* 23. There was mal-union of the radius and a large gap in the ulna.

FIG. 68 A.—The same bones after operation. As the radius was displaced away from the ulna, it was left alone. The ulna was united by a long tibial graft, pegged into the lower fragment and united to the upper by two split pins.

3. Finally, the use of wire nails, screws, bolts, or plates as a method of fixation must be considered. And in this connexion it is wise to hold a temperate and reasoned opinion which avoids impracticable extremes.

The fact that wire plates and screws have often been unwisely used and caused trouble is not sufficient reason to reject metallic suture when this will afford definite advantages. That there is nothing essentially hostile to a graft in the presence of metal sutures is proved by the many cases in which success has followed this method of fixation. In thirteen out of nineteen successful cases in the present series, metal sutures were used. If it is admitted on the one hand that firm fitting without metal sutures is always the ideal method of grafting, it must, I think, also be granted that firm fixation by metal sutures is better than insecure fixation without, and I have given experimental demonstration of this. There

FIG. 69.—Tibia from *Case* 43. Successfully united by an inlay graft from the opposite tibia fitted without the use of metal sutures.

are many cases where the graft has to be laid with some tension—i.e. the graft itself has to act as a splint securing alinement. Such a case is well illustrated by the common fracture of the radius—cf. *Case* 6, Figs. 64, 64 A. In such a case, if a strong graft is securely bolted or pinned to its bed, then it will heal well ; whereas if it was merely tied in its place, it would surely allow angulation to occur, and probably the graft would be extruded.

I have successfully used encircling iron wire, split pins, bolts, and plates for the fixation of a graft, and these various methods are so well shown in the accompanying radiograms that it is hardly necessary to describe them in detail. The split pin is, however, the method which gives me the greatest satisfaction. These pins are the ordinary cotter-pins to be bought at any ironmongers. I use them in thicknesses of $\frac{1}{16}$, $\frac{3}{32}$, and $\frac{1}{8}$ in. The bone bed and the graft are perforated by a suitable drill, the pin thrust through, and its ends are turned up and cut off and pressed home (Figs. 63, 63 A, 66).

Another point to be borne in mind is that the use of firm metal fixation will greatly simplify after-treatment, inasmuch as much less plaster-of-Paris immobilization is then required. In the forearm bones, for example, the limb is kept on a simple splint for a few days until the smooth healing of the wound is secured ; then plaster is applied for two or three weeks ; and after this the man is set to light work without any splint or plaster of any kind ; and I claim that in this way much more rapid restoration of function is obtained than by keeping the limb for months in plaster.

A complete list of 60 consecutive cases, on which this paper is founded, is given in the article in the October 1918 number of the *British Journal of Surgery*.

MAL-UNION OF FEMUR

BY

SIR ROBERT JONES

MAL-UNION OF FEMUR

BEFORE the war, cases of mal-union of the femur were very common in which angulation with considerable shortening was found; but experience gained during the war has taught the surgeon to be content with nothing less than a perfectly united fracture with full length and good alinement of the limb. Mal-union is quite unnecessary, and is the result of want of knowledge or attention on the part of the surgeon. The deformities seen during the early part of the war were caused by rapid evacuation and want of continuity in treatment.

There are many ways of treating fractures. Some surgeons employ plaster, some weight and extension, and some fixation and retention; but whichever method is adopted, a good result is only to be obtained by careful personal attention devoted from the time of injury until consolidation occurs. Mal-union frequently occurs when the patient begins to walk on the unsupported limb. The fracture has apparently become perfectly united and callus is seen round the broken ends in the X-ray photograph, and no movement can be elicited by manipulation. Experience before the war demonstrated that fractures of the femur require months rather than weeks to become sufficiently united to bear body-weight. The fractures of the war require even a longer period because of the effects of suppuration and the severity of the injury.

The length of time required for the complete union of fractured bones varies. In one case the process of healing may be completed in eight weeks, but in another case of fracture of the same bone the time required may be five or six months. There is usually only one clinical sign on which reliance can be placed, and that is tenderness at the site of fracture. It may be stated that, as a rule, the presence of tenderness over the callus at the site of fracture is a definite indication that the callus is still soft and will yield on the application of strain. The only rule that can be made regarding any fracture of a large bone, such as the femur, is that the weight of the body should not be allowed on the unsupported femur for at least six months after the recumbent treatment of the fracture.

Mal-union of Fracture of the Shaft of the Femur. Here we find, perhaps more than in any other bone of the body, every degree of mal-union from the bowing outwards, which is commonly situated close below the lesser trochanter, to the crippling degree of the posterior bowing which

is seen when the two fragments are allowed to fall back, giving rise to a genu recurvatum which is very damaging to the knee-joint. We may count on at least one of three displacements, which are : (1) overlapping ; (2) angulation ; (3) rotation.

It is seldom that we have to deal with only one of these deformities—often with all three—but generally with a combination of angulation and overlapping. This is due to inefficient traction and lateral control. We should therefore secure ample traction, lateral pressure, and a correct axis. Angulation and rotation are more serious from the point of view of function than shortening. Operation is called for to correct erratic deflection of body-weight upon joints, to correct rotation and to correct marked shortening when this is feasible. Operation is contra-indicated in the presence of sepsis, or when sepsis has been recent, or when shortening is under two inches. Even marked angulation in a badly nourished limb with abundant scar tissue should be approached with a serious sense of responsibility, and if an operation be performed it should be as simple as can be devised. An osteotomy is usually sufficient to restore alinement.

With regard to the shortening of the limb, one must clearly differentiate between real and apparent shortening. Real shortening is due to loss of bone, faulty alinement, or to overlapping of the fragments, and is measured from the anterior superior iliac spine to the internal malleolus. Apparent shortening is due to elevation of the pelvis on that side of the body, causing the foot to be raised from the floor, and can easily be demonstrated by measurement from the umbilicus to malleoli. Apparent shortening can easily be overcome by voluntary effort or by extension, therefore no operative interference is required. In war injuries, very marked apparent shortening of the leg is often seen. On measurement it is found that the real shortening is comparatively slight, and that the tilting of the pelvis has been superadded and has caused most of the deformity. It results from the patient's efforts to bring the maimed limb parallel with the sound one, and so the practical shortening is increased.

In correcting these deformities we should be quite certain in the first place as to whether the fracture is completely consolidated, because, if not, reapplication of an extension splint and gradual straightening may be all that is required ; and even in attempting this, great care must be taken, as many cases have betrayed a violent recrudescence of sepsis by a simple gentle manipulation of a still infected fracture.

Our aim in cases of mal-union is not so much the anatomical reposition of the two fractured ends, as the restoration of the line of action of all the muscles and joints on each side of the fracture. Sometimes function may be almost perfect with a marked overlapping, provided alinement is good. Cases are sometimes seen where an apparently useful limb is

obtained in the presence of marked deformity. They are distinctly exceptional, and, sooner or later, the joints above and below the fracture give trouble. This is especially the case where the posterior sagging of the lower end of the femur results in genu recurvatum, or when a continuous strain is applied to the lateral ligaments of the knee. Angulation is often accompanied by considerable callus exudation, which interferes with the free play of muscle groups.

Angulation. This can often be corrected by lateral pressure and extension, when the bone has not fully consolidated. It may be necessary to assist by manipulation under an anæsthetic. If there is overlapping, continuous extension will usually diminish it. If consolidation is complete, an operation may be called for—the type of operation depends upon the condition of the patient, and of the limb. If the fracture has been a simple one, an effort should be made to restore the bones into position, and to freshen the fractured ends. If there has been suppuration, and scar tissue abounds, an operation which aims at exposing the fractured ends outside the wound is serious, and only under very exceptional conditions should it be resorted to. In such a case, the shortening should be ignored, and the angulation alone be corrected by osteotomy. There is but little risk in such an operation, and the worst functional features of deformity are overcome.

Osteotomy is the operation of choice. It can either be performed along the line of overlapping fracture or through the angle, or just above the fracture. The surgeon will be guided by the X-ray picture. It will be found that an incision through the angle will usually give the best practical result. The incision should be oblique from without inwards and upwards. A broad osteotome is the most useful and practical implement.

Overlapping is usually accompanied by angulation, and if it is marked the osteotome should pass between the bones in order that both angulation and shortening should be overcome. The lengthening may be started by a cautious application of the pulley, followed by continuous extension or by extension and retention.

Genu Recurvatum should be corrected by a supracondylar osteotomy, and great care should be taken in the after-treatment to obliterate the posterior sagging of the lower end of femur.

Rotation can be ignored unless it interferes with function. The osteotomy can be performed through any part of the femur away from the fracture.

The after-treatment must be conducted properly. If it is no better than the treatment adopted in the first instance, the result will be a tragedy. A mal-united fracture cannot be cured by operation. All the operation can do is to reconstruct the fracture. The surgeon must not

merely reduce the fracture but must maintain the corrected alinement until consolidation of the bone is secured.

In an operation for fracture of the femur I never use plates, and the experience of surgeons gained in the war shows how admirably these fractures can be treated by properly applied traction and prolonged protection.

When possible, it is always advisable to mobilize stiff joints before refracturing the femur.

THE TREATMENT OF CHRONIC OSTEOMYELITIS

BY

MAJOR R. C. ELMSLIE

THE TREATMENT OF CHRONIC OSTEOMYELITIS

In civilian surgery compound fractures are usually kept free from severe septic complications by modern methods of treatment. The rapid aseptic healing of the wound leaves a fracture which does not differ essentially from a simple one. In military surgery the fate of compound fractures is very different, the severity of the injury, the comminution of the bone and the laceration of the soft parts themselves tend to produce tissue necrosis, which, by supplying the suitable pabulum, assists the growth of micro-organisms and renders the supervention of sepsis much more probable. In addition many wounds contain foreign bodies, either the missile itself or particles of clothing, or earth and débris; these frequently contain bacteria which are thus inoculated into the wound, into the midst of necrotic tissue which serves as a culture medium equal to, or better than, any that can be provided in a laboratory. The conditions under which the patient is treated in the early stages may render any attempt to cleanse the wound impossible during the first twenty-four hours, after this time pyogenic organisms have had time to multiply in the devitalized tissues and septic complications are inevitable. For these reasons many of the compound fractures of war surgery are complicated by a septic infection of the area of the injury, the bone is almost certain to be involved in this infection, a septic osteomyelitis resulting.

Fortunately this osteomyelitis does not invariably or even usually take the form of the acute spreading osteomyelitis seen in civil practice; it is more often subacute, becoming later chronic, yet it gives rise to the same dangerous and troublesome complications as are found in the acute disease. Pus extends under the periosteum, in the medulla, between the bone fragments and into the surrounding tissues. There may be a period of acute illness and operations for the evacuation of pus may be necessary; sooner or later, however, the condition quiets down, chronic osteomyelitis with sinuses leading to cavities in the bone and to sequestra remaining. When early treatment is possible the routine method is to excise all the damaged tissue in the wound, commencing with the damaged margins of the skin and proceeding deeper and deeper through the wound. When there is a compound fracture the surgeon is faced with a dilemma; in order to cleanse the wound thoroughly he should remove all the comminuted fragments of bone and also the ends of the main fragments from which they have been detached. It is possible that after doing this, he

will have left a continuous tube of periosteum from which the bone can be regenerated, but in order to cleanse the wound thoroughly it may be necessary even to remove portions of the periosteum ; such a thorough operation is of course possible, but it must inevitably lead to a very grave risk of producing non-union of the fracture. For this reason most surgeons have been satisfied with a less thorough cleansing followed by the use of Bipp or Dakins's solution, or whatever particular antiseptic they may favour. In many cases sepsis is eliminated or controlled, but it is clear that septic complications cannot be absolutely abolished in these cases of bone injury in the way that they can be by primary excision of a wound of the soft parts.

Chronic bone sinuses resulting from septic compound fractures are thus very frequent and very intractable, how intractable we may gather from the history of past wars, and of veterans whose wounds remained healed for a time but broke down at intervals, discharging a little pus, and then healing until the next exacerbation took place. It may be predicted that the chronic bone sinus will be one of the outstanding features of surgery long after the war is over. It is essential that the rational treatment and cure of these cases should be taken firmly in hand.

The mere persistence of a sinus leading to necrosed bone is only one part of the trouble. The sinus in itself is an inconvenience to the patient, but may not add greatly to his disability ; it has, however, other results which are of greater importance. In the first place the compound fracture is usually only part of the injury ; there may in addition be damaged muscles and tendons which can be repaired surgically, or a nerve may be divided and require suture. The fractured bone may not unite, so that an operation upon it becomes necessary, or the fracture may involve a joint which becomes fixed and must be treated by surgical or physical means. Even in the absence of these larger complications the original injury, or the septic infection, will almost certainly have caused more or less matting and fibrosis of the muscles with a consequent restriction in the passive and active movement of the neighbouring joints. All these conditions require surgical or physical treatment which may be rendered dangerous or impossible by the presence of continued sepsis. Although we now know that it is possible, given proper methods and precautions, to perform operations in the presence of sepsis without our wound becoming acutely infected, yet every surgeon still naturally prefers to operate in a clean field, and certain operations such as grafting a bone or modelling a new joint necessitate absolute asepsis and must be postponed until this can be secured. We know that a septic focus can be shut in in the tissues and remain dormant over a long time ; in operating this focus may be opened with a knife and may thus infect the wound. When a simple manipulation of a joint is carried out such

a concealed focus may also be opened, its walls being ruptured and its infected contents set free in the tissues where it produces an attack of cellulitis. Thus simple manipulations, or even massage, may produce a recrudescence of the sepsis. Yet it is most important that these forms of treatment, operative, such as nerve suture, repair of tendons or bone grafting, and physical, such as manipulation and massage, should be carried out without delay, so that the tissues and organs may resume their function and the patient's disability be lessened as early as possible. The presence of sepsis delays these procedures, therefore we must eliminate sepsis as soon as we possibly can, even adopting radical procedures of considerable boldness in order to arrive at this end.

A second reason for advocating a final cure of all sinuses is that these in themselves must affect the patient's health. Not only is there a continuous septic absorption from the sinus, but in addition exacerbations of infection are liable to occur from time to time even without any apparent cause. These exacerbations may take the form of a cellulitis, or a localized abscess, or there may be a fresh attack of osteomyelitis with necrosis of additional pieces of bone. No patient should be left in a condition which leaves him liable to these recurrent illnesses ; we ought to adopt some procedure which will cure his sinus once and for all.

Excision as far as is possible of the original wound and its treatment with antiseptics may have resulted in early healing with an apparent absence of sepsis ; but this may be fallacious. It is not unusual to find a hidden focus of infection in a wound that has been healed for three months or more. There may be, deep in the wound, a cavity in the bone lined by granulation tissue and containing a few drops of pus and perhaps one or more sequestra. Such a dormant focus of infection has been found in a wound which had remained healed for eighteen months, and the staphylococcus aureus cultivated from the pus. If a discovery of this sort is made in the course of an operation, the surgeon has practically no alternative but to postpone the completion of his operation, satisfying himself for the time by cleaning out the pocket of pus and preparing the way for a later attempt to carry out his original intention. These hidden foci of suppuration may be guessed at from the appearance of an X-ray photograph ; their presence, however, can only be proved during an operation.

There is another condition in healed war wounds which may endanger the result of a late operation ; in many old wounds the scars are thin and adherent, their nutrition being poor. If such a scar is reflected in a flap there is a strong probability that its nutrition will fail, it then sloughs or dissolves away leaving an area which must heal by granulation, and in which possibly a sutured nerve or tendon, or possibly a bone graft, may be exposed. The dangers arising from concealed sepsis, and from

thin adherent scars, render it advisable to perform a preliminary operation for the excision of scars and exploration of the deep tissue before many of the major operations of military orthopædic surgery are undertaken.

PATHOLOGY OF OSTEOMYELITIS

In osteomyelitis as seen in civil surgery there is to begin with an acute inflammatory effusion under the periosteum, in the medullary cavity, and in the Haversian canals ; this effusion becomes purulent so that the periosteum is stripped from the bone by a layer of pus, and pus is contained in the medullary cavity and other spaces in the bone. Necrosis takes place owing perhaps partly to the chemical results of the infection, and partly to interference with the circulation in the compact tissue of the bone. The latter is probably the chief agent in producing massive necrosis, and for this reason we see sequestra form from bone, the periosteum of which has been stripped. When the pus has been evacuated either naturally or by surgical incisions the acute inflammatory process quiets down, and is succeeded by chronic osteomyelitis with sinuses leading down to the necrosed areas of bone. Meanwhile new periosteal bone is formed as the result of the activity of the osteoblasts of the stripped periosteum. This tends to produce a new bony shaft which surrounds the necrosed bone entirely except at those spots through which the pus has escaped (cloacæ). The chronic condition persists until the sequestra have had time to separate, and after this until these sequestra have escaped or been removed, and the cavities which contained them have become filled up with a new healthy tissue. The great obstructions to the final cure of chronic osteomyelitis are, first, the fact that the sequestra are enclosed by new bone, and that the cloacæ are often too small to allow them to escape ; and secondly, that even after the sequestra have been removed, there remain cavities in the bone lined by granulation tissue infected with pyogenic organisms, and surrounded by hard new bone which has neither the power to produce new tissue which can extend into and fill the cavity, nor the ability to fall in and so obliterate the cavity in the way that the wall of an acute abscess in the soft parts falls in.

The course of an osteomyelitis which commences at the site of the fracture is similar in most respects to that of the simple non-traumatic form ; the chief difference is that there is an initial wound leading to the bone, so that the purulent effusion has a potential exit from the first. For this reason the stripping of the periosteum and the extension of the pus in the medullary spaces is less, so that necrosis of the bone, although it is almost invariable, results in the formation of smaller sequestra. In addition, the periosteum tends to be more torn so that the sheath of the new periosteal bone is less complete and the exit of sequestra more

possible. In spite of these two favourable circumstances the formation of sequestra, their enclosure by new bone, and the eventual production of cavities which cannot heal is extremely common in the osteomyelitis of compound fractures. So that we may say that almost all chronic sinuses resulting from compound fractures lead down either to a sequestrum or to a cavity in the bone lined with infected granulation tissue and surrounded by hard bone or dense scar tissue. It is true that in many compound fractures sequestra separate and come away or are removed by the simple operation of curetting, nevertheless even in cases in which this occurs the sinuses frequently fail to heal either because other sequestra are present or because a cavity remains to be filled up. For this reason it is a mistake to adopt an expectant attitude and to treat chronic osteomyelitis by curetting except in particular cases which occur mostly in the small bones.

It is apparently believed by some surgeons that the sequestra found at the late stage in a compound fracture are formed by the necrosis of the small pieces of bone which resulted from the original comminution. This is unfortunately not true; necrosis in compound fractures is due to sepsis and not to the separation of fragments of bone from their attachments. It has been proved that it is possible to transplant fragments of bone without periosteal attachments from one part of the body to another and for fragments to live and grow. In gunshot fractures in which the wounds are small, and which have healed aseptically, necrosis does not occur even when there has been much comminution of bone. It is not even true that the septic infection tends to produce necrosis chiefly in the small fragments. In most compound fractures it can be recognized that the largest sequestra and those which give the most trouble are derived from the extremities of the main fragments of the bone; they are in fact analogous with the ring sequestra which separate from the cut end of the bone in a septic amputation stump. These sequestra show along one margin the clean straight broken edge produced by the fracture, along another margin the jagged dented edge produced by the ulceration by means of which they have been slowly separated from the healthy bone. The importance of realizing that sequestra are due to sepsis and that they are derived as often from the main fragments as from comminuted portions will be seen when it is remembered that some surgeons believe that by the early removal of comminuted portions of bone they can prevent subsequent necrosis. This is only true if by such a removal they can absolutely eliminate septic complications. Such a removal of comminuted fragments undoubtedly leads to a possibility of non-union of the fracture; its utility in the early stages is still problematic. When once sepsis has supervened a general removal of comminuted fragments is to be condemned as irrational.

The consideration of the pathology of chronic osteomyelitis leads then to the conclusion that a sinus is kept up either by a sequestrum in its depth, or by the existence of an infected cavity, the walls of which are unable to collapse and allow of its obliteration. If we are to cure the sinus completely and quickly we must first examine and determine the exact extent of the cavities and tracks in the bone and soft tissues and then perform such an operation as will remove all sequestra, open and clean all cavities and septic tracks and set free soft tissues so that they can fall into any cavity and obliterate it.

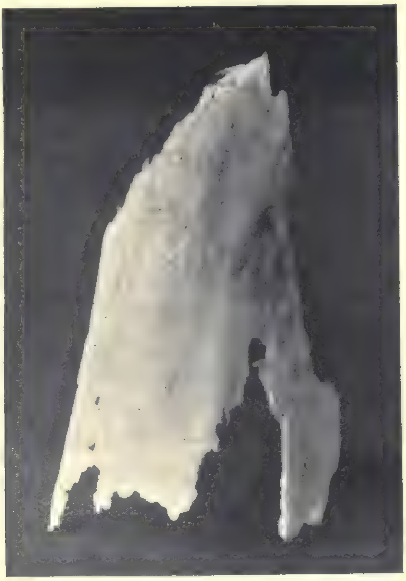


FIG. 70.—Sequestrum removed from an infected compound fracture of the humerus. It had separated from the end of one of the main fragments. The upper edge is that produced by the fracture; the lower dentate edge is that produced by separation by ulceration from the shaft of the bone.

INVESTIGATION OF A CHRONIC SINUS

The first step in investigating a sinus should be the careful use of a small probe; the end of the probe should be blunt, and persuasion rather than force should be used. It is comparatively easy to push the ordinary probe through the wall of a sinus and so to make a new false track. In many cases the probe will enter a cavity or tunnel in the bone and perhaps feel a sequestrum; it is only rarely that the track thus explored will prove to be the only one or that the sequestrum will be single. The next step is the X-ray examination; plates should be taken in two planes at right angles to one another if this is possible; the

insertion of a probe into the sinus so that its shadow is seen in the X-ray may be of assistance. A stereoscopic photo with the probe *in situ* will often demonstrate that the sinus leads into the cavity or tunnel. Sequestra, as a rule, throw a shadow which is denser than that of healthy bone; it may be possible to be sure from the appearances seen that the sequestra are separated, but often we must judge of this separation by the time

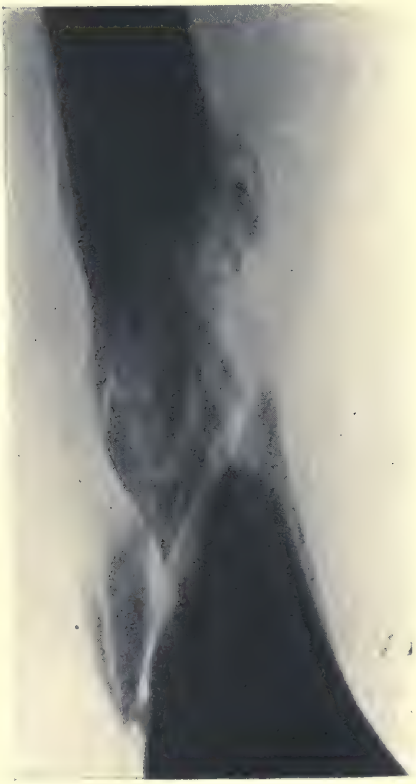


FIG. 71.—Skiagram of a compound fracture of the femur. A large V-shaped sequestrum is seen between the main fragments; it has separated from the upper fragment.

which has elapsed since the fracture. In most bones three months is a sufficient period to allow for separation, in the smaller bones such as the radius and ulna six weeks or two months is enough, in the femur three to four months are required, and in the tibia sometimes even five or six months.

Much information may be gained by the injection of bismuth paste into the sinus. The paste is melted and injected with a glass syringe and allowed to solidify; X-ray photographs are then taken and

FIG. 72.—Skiagram of a compound fracture of the humerus. A sinus was kept up by the presence of a cavity in the bone, no sequestra being present. Eight previous operations had been performed. Removal of all scar tissue and obliteration of the cavity by bevelling its margins and inserting a flap of the deltoid muscle resulted in healing within a month.

compared with those taken before the injection. The following mixture may be used:

Bismuth sub-nitrate	30 parts
Cera alba	10 ,,
Yellow paraffin	70 ,,
Formaldehyde	1 ,,

The object of the X-ray investigation should be to form a clear conception of the whole damaged area including the position and shape of sequestra, the existence of cavities and septic tracks and their exact situation. Usually it will be found that the tracks and cavities represent spaces which existed between the original fragments of the fracture, and the sequestra represent the extremities either of the main fragments or of small parts which have been completely separated. Hence in a comparatively simple fracture it will often be found that there is an oblique track through the bone containing one or two sequestra which have separated from the broken ends and which have become enclosed by the new periosteal bone. In a more complicated case with much comminution, there is often a large cavity in the bone perhaps leading right through between the main fragments, surrounded with bone, part of which is new, part of which contains comminuted fragments. Between these fragments septic tracks may lead from the main cavity to the exterior, and in the course of these tracks there may be small sequestra which have separated from one of the smaller fragments. In such a case the whole picture is very complicated, and although the general idea of the condition may be arrived at by a careful X-ray examination it will often be found that discoveries are made at the operation of sequestra and of septic tracks which were not suspected beforehand.

RADICAL OPERATION ON A BONE SINUS

When the pathology of chronic osteomyelitis is understood the futility of any method of treatment which fails to attack the real cause of a persistent sinus becomes evident. It is still not unusual to find chronic sinuses energetically treated by plugging with special dressings, or by the injection of new fashioned chemicals. It must be obvious that these methods cannot bring out a sequestrum nor can they assist the hard walls of a cavity in a bone to collapse. The only rational treatment of a chronic bone sinus is surgical, and if a single operation is to suffice this must be of a radical nature and include the removal of all sequestra, the removal of septic tissue, and some procedure which will free the soft parts so that they can fall into and obliterate the cavity.

Much has been written in the past upon filling cavities in the bone, and many special materials have been devised for this purpose; when

a cavity in a bone is aseptic, as for example, after curetting out a bone-cyst, it is unnecessary to insert any material whatever, the space will fill with blood-clot which becomes organized and eventually replaced by bone, marrow, or fibrous tissue. It is very different with the cavity which is infected ; here, as already explained, we get densely hard sclerosed walls, a lining of granulation tissue, and purulent contents ; such a cavity can only fill by a very slow growth from the granulations, and even this process is limited so that a cavity of any size never fills at all. The insertion of foreign substances such as some of the wax or paraffin pastes is quite safe and efficient in aseptic cavities, but in them it is unnecessary. In septic cavities these foreign materials act as irritants and tend to be gradually eliminated with the purulent secretion. If a septic cavity is to be filled this must be done by using an actual living tissue for the purpose ; it is upon this principle that the operation now to be described, which was originated by Professor Broca, is based.

The chronic sinus having been investigated as fully as possible by X-rays and other methods, an operation should be undertaken with a view to curing it forthwith. This radical operation will, however, not be undertaken until sufficient time has passed after the injury to allow of the separation of sequestra and of the development of a considerable resistance to infection in the tissues ; practically then the time for the operation is from six weeks to four or five months after the initial injury to the bone affected according to the time necessary to allow of separation of the sequestra. The patient should be fully anæsthetized with chloroform or ether, no attempt should be made to operate upon a sinus under a short gas anæsthesia, for although the operation may last only a few minutes it may equally well last an hour. The use of a tourniquet makes the operation simpler and renders it possible to explore the bone more thoroughly. As, however, an extensive area will be opened up there will be much bleeding afterwards and the use of a tourniquet naturally increases this and renders it essential to drain the wound. The surgeon who is inexperienced in these operations should use a tourniquet whenever possible ; he will find that he is able to complete the operation more thoroughly and more rapidly. With increased experience he will be able to dispense with the use of a tourniquet and probably by this means get more rapid healing.

The first step is again to probe the sinus, or sinuses, carefully ; supposing that these do not lead to bone, and the X-ray evidence has failed to prove the presence either of a sequestrum or of a septic cavity, then the sinuses should be thoroughly opened up and curetted, any foreign bodies being looked for. If in opening up the sinus a secondary track is found, this must also be carefully investigated. When the sinus is very chronic and its walls extensively indurated it will be better

instead of slitting it up, to dissect it out altogether, cutting away on all sides until healthy tissue remains. The skin edges should then be freed by undercutting, the wound treated with Bipp and sutured. If the exploration has been carried out as a preliminary to a later operation upon the bone or upon a joint, tendon, or nerve, this excision of scar tissue should be made as a matter of routine.

If the sinus leads down the bone, a radical operation should be undertaken, an incision must be made along that aspect of the bone which gives the best approach ; this may or may not include the sinus, if it does the old scar of the sinus should be excised. It may be necessary

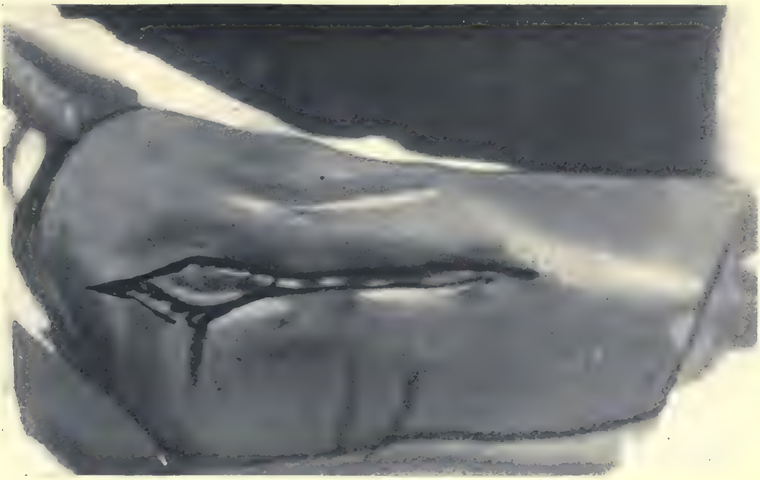


Fig. 73.—Radical operation upon a sinus leading down to a compound fracture of the femur. Incision along the outer side enclosing the sinus and an old scar.

to make the incision 6 or 8 in. long, or even more, exposing the bone for almost this length. It will be evident that such an exposure can only be carried out along the most favourable aspect of the bone, for example, the femur can thus be explored along its external surface, or the humerus along the line of the external intermuscular septum. If a sinus on the inner side of the thigh leads down to the femur, it would be impossible to expose the bone adequately by enlarging it ; the sinus should be ignored in making the incision for a radical operation and only examined later when the bone has been thoroughly exposed. If necessary a double incision must be made ; this is particularly indicated in sinuses leading to the ends of the long bones. A chronic osteomyelitis of the lower end of the femur may require exploration from both the external and the internal aspects, because the width of the bone is too great to allow of a complete inspection from the outer side. The incision having been

made, it is carried down to the bone and through the periosteum; the incision through the periosteum should first be made over healthy bone above and below the site of the old fracture; at these spots it is a simple matter to strip everything away from the bone sub-periosteally, a strong periosteal elevator and the large bone levers used for plating being the best instruments. Working from these points upwards and downwards towards the fracture, the damaged site of the bone is next completely exposed; the periosteum and scar tissue can be lifted away partly by force, partly by cutting with a knife. If a start is thus made where the

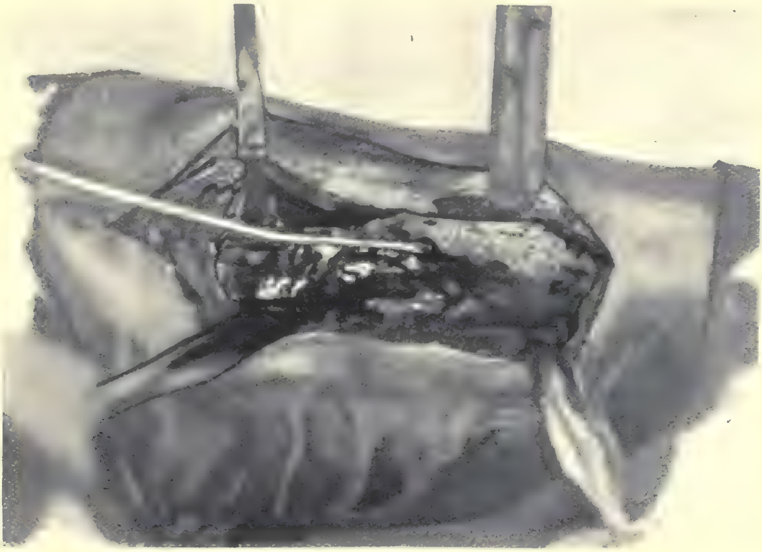


FIG. 74.—Radical operation upon a sinus leading down to a compound fracture of the femur. Exposure of the whole bone at the site of fracture. A probe has been inserted into a large cavity in the bone.

bone is healthy, stripping is easy. If an attempt is made, however, to attack the damaged site of the bone directly, it may be a very difficult matter to gain a good exposure.

The whole of the injured and septic area now being exposed, the wound in the soft parts around should be packed lightly with gauze; next, every track and cavity in the bone must be explored and laid open, a close watch being kept throughout for any additional tracks or tunnels. Curved chisels of different sizes should be used to open up thoroughly every cavity or tunnel in the bone, the whole of the outer wall of a tunnel being removed and the floor being cut away until healthy bone is exposed and until the tunnel is flattened out, so that it no longer even makes a groove. Large cavities are similarly dealt with; one wall must be

removed and the edges of the cavity bevelled down from above, below, and the sides, until the surface remaining is as flat as possible, contains no deep pits, and consists of healthy bone or callus. No pit or track lined with granulations should be left. Considerable judgement is necessary in deciding which wall of the cavity should be removed; sometimes it is impossible to cut away bone sufficiently to flatten out the cavity completely without endangering the strength of the bone at the site of the fracture; in this case the margins of the cavity must be well bevelled, so that instead of forming a deep pit it forms rather a basin with shelving sides into which the soft tissue can fall and in which there is no risk of the subsequent enclosure of fresh sequestra if these are formed. In many cases a track or cavity passes right through the centre of the bone, and it may be found undesirable to remove completely one of its walls inasmuch as this would involve reducing a thickness of the bone by at least one-half. In this case the cavity should be converted into a large hole through the bone, the edges of which are bevelled down thoroughly on both sides; often the wide opening up of such a tunnel through the bone will be justified immediately by the discovery of a sequestrum upon the deeper and more inaccessible side; such a sequestrum could only have been discovered by this very free enlargement of the tunnel.

In some cases the free removal of bone will result in refracture; this is less serious than might be thought, for the cases in which refracture occurs are nearly always those in which union is unsound, and in which the fragments are in bad alinement. The surgeon need never feel that his methods have been bad, or that he has done harm to the patient by producing such a refracture.

The objects of this stage of the operation are:

1. To open up all tracks and sinuses and to leave no possibility that there are hidden sequestra;
2. To remove all granulation tissue exposing healthy bone or callus beneath it;
3. To flatten the surfaces of the bone so thoroughly that if superficial sequestra form as the result of sepsis after the operation, they will not become enclosed in callus but will be free and easily removed;
4. To shape the bone so that no cavity with rigid walls remains which cannot be filled by the falling in of the soft tissues around.

No two cases are alike, but the surgeon, if he realizes these objects for which he is working, will see that thoroughness is the essence of the whole procedure. If an unexplored track remains there may be a hidden

sequestrum acting as a fresh source of infection. If granulation tissue is left it acts as a point from which micro-organisms can infect the whole wound. The formation of a fresh enclosed sequestrum, or the leaving of an unobliterated cavity, will obviously leave a condition similar to that which we set out to cure. It is important to see that no flecks of bone which have been cut off with the chisel remain in the wound; these will form foreign bodies and may keep up subsequent suppuration until they are discovered and removed.

Fig. 75.—Radical operation upon a sinus leading down to a compound fracture of the femur. The outer wall of the cavity has been removed and the bone thoroughly cleaned. A flap of vastus externus has been cut for insertion into the depression left in the bone.

Any scar tissue around the bone should next be removed if this is safe and possible. At the same time sinuses in the soft parts should be explored; they need not necessarily always be excised although this is the ideal method; they should, however, be examined with the finger to make sure that they do not contain any foreign body or sequestrum. It is particularly necessary to examine scar tissue which has been lifted from the bone upon its deep aspect. In some cases when this scar tissue is lifted away a sequestrum goes with it and escapes subsequent removal; such a sequestrum will keep up persistent suppuration and will lie at such

a depth that its spontaneous escape is almost impossible. Having now prepared the bone and removed the scar tissue as far as possible, it is necessary to determine whether the muscles can fall into place against the bone without leaving unobliterated spaces. In very many cases it is necessary to free muscle tissue, so that it can fall in against a cavity remaining in the bone and fill it completely. No hesitation need be felt in cutting deliberately a considerable flap of muscle for this purpose. As a rule the muscle fibres will be cut off from their nerve supply and their function abolished ; they will eventually become converted into fibrous tissue, but muscles are of little use if they exist in a segment of a limb

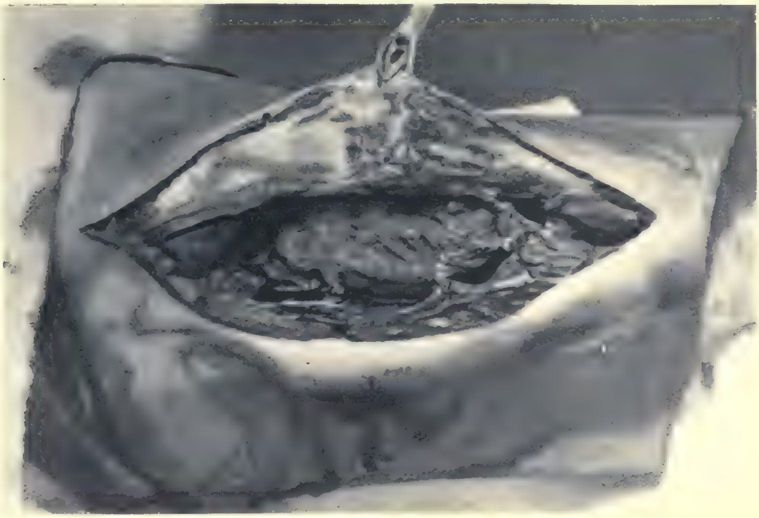


FIG. 76.—Radical operation upon a sinus leading down to a compound fracture of the femur. The muscle flap has been stitched into place with catgut.

whose function is damaged by the existence of a chronic sinus ; the sacrifice of a certain amount of muscle tissue in order to cure a sinus is a perfectly reasonable and justifiable procedure. In cutting the flap it is preferable to use a muscle which is attached to the bone and which can therefore be lifted with periosteum upon its deep surface ; by so doing the periosteum may be made to lie against the floor of the bone cavity, where it will subsequently lead to the production of new bone, thus strengthening the fractured site.

The bone being prepared, the scar tissue excised and the muscle flap cut, the wound is ready for suture except that it requires antiseptic treatment. It must be remembered that the wound is infected, the number of micro-organisms present may be few and the resistance of the tissues considerable ; still simple aseptic healing can scarcely be expected.

The best form of antiseptic for use is one that has a continuous action, that is a chemical substance, or compound, which undergoes a change in the tissues slowly setting free such an antiseptic as iodine, or chlorine, probably Bipp is the simplest and best of these. The whole wound should first be dried out thoroughly with methylated spirit, Bipp should then be taken and rubbed into the surface of the bone, muscle, subcutaneous tissue, and skin, plenty of the paste being used. Clean swabs should then be taken and the Bipp rubbed away as carefully as it has been rubbed in, every particle that can be removed being got rid of and great care being taken not to leave any mass of the paste in any little

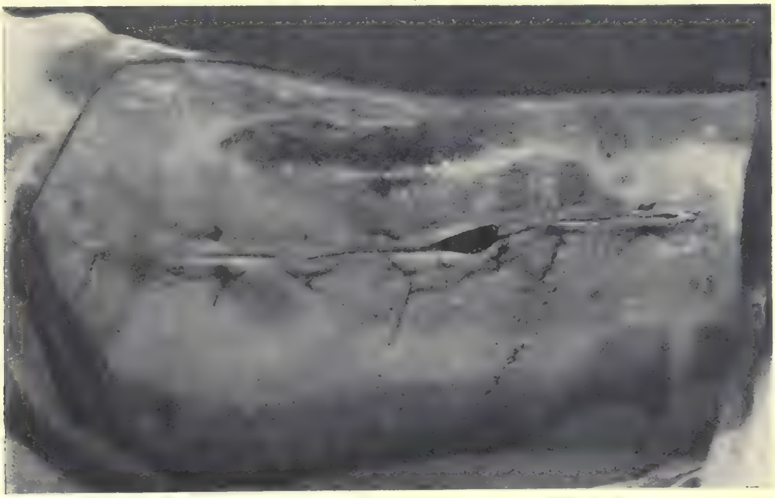


Fig. 77.—Radical operation upon a sinus leading down to a compound fracture of the femur. The wound sutured with drainage.

pocket. There are two reasons for getting rid of the Bipp: first, that this paste lying in freshly cut tissues may be absorbed to a considerable extent and give rise to symptoms of poisoning; and second, that any mass of the paste may act as a foreign body and perhaps help to keep open the sinus. The wound having been treated with Bipp, the muscle flap is laid into its place and fixed with an easily absorbable catgut suture. Unless the wound is very dry tubes should be inserted for drainage; the surgeon is advised to drain until he has gained considerable experience, he may then be able to judge that in certain cases he can dispense with the tube and secure primary union. In suturing the skin, it is necessary to avoid inversion of the edges; the special suture shown in Fig. 78 is useful for this purpose. A dressing of cyanide gauze is advisable; it should be applied with plenty of wool and with firm pressure, and left in place for eight days, if possible. If there is no rise of temperature the dressing

may be left the full time, the tube and stitches then removed and the tube track left to granulate ; if there is much rise of temperature the wound must be dressed earlier and drainage kept up. Cyanide gauze is recommended because if plain sterile gauze is used the dressing often becomes offensive.

In nearly all cases the greater part of the wound heals by first intention ; the sinus left by the tube may be healed within a fortnight, or it may persist for one or two months ; if it remains unhealed after two months a re-exploration will probably be necessary. The causes of failure in such a case are that either a sequestrum has escaped notice, or a new sequestrum has formed and is too large or too much enclosed to be able to escape, or a cavity has been left and the muscle not freed

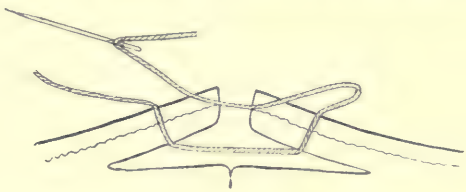


FIG. 78.—Skin suture used to avoid inversion. The suture is first passed through the whole thickness of the skin ¾ in. from the margin ; it is then returned through the skin edge.

sufficiently to obliterate it ; the possibility of lifting a sequestrum aside and so overlooking it, or of leaving a chip of bone in the wound has already been mentioned.

EXPLORATION OF SPECIAL BONES

The Femur. The femur can be explored from the tip of the great trochanter to the external condyle along its outer side, the incision being carried through the vastus externus muscle ; the only parts of the bone which cannot be adequately dealt with through such an incision are the head and neck and the lower end. The head and the neck of the femur must be explored by one of the incisions used for excision of the hip-joint, the anterior or posterior incision being adopted according as it is believed that the chief sequestrum lies in front or behind. The lower extremity of the femur will often need exploration by a double incision—one along its external aspect, the other along the antero-internal aspect. The vastus externus muscle is that which is chiefly used for cutting the muscle flap ; a cavity in the internal condyle may, however, be filled with a portion of the crureus or vastus internus muscle.

The Tibia. The tibia is an easy bone to explore because so much of it is subcutaneous ; it is, however, very difficult to find material with

which to fill any remaining cavity. If the cavity can be left exposed along the postero-internal border, it may be possible to fill it with a portion of the soleus muscle. In cutting the flap from this muscle, great care must be taken not to go too deeply and to injure the posterior tibial vessels and nerves. In the upper part of the leg a small flap can be obtained from the tibialis anticus muscle, but comparatively little muscle tissue can be cut without risking damage to the anterior tibial nerve. In many cases it is impossible to fill a cavity in the tibia with muscle, and some other manœuvre must be adopted. The simplest method is to crush in one of the borders of the bone so as to obliterate most of the cavity, filling the remainder with a small muscle flap. For example, a cavity the size of a large walnut on the inner side of the head of the tibia was explored and found to extend downwards into the shaft for about 3 in. A groove was cut into this from the subcutaneous surface of the bone, a number of sequestra removed, and the whole of the long cavity left thoroughly cleaned ; this cavity was then about 4 in. long and 1 in. deep. It was bounded anteriorly by the crest of the tibia and posteriorly by the postero-internal border, the latter border was chiselled through at the upper and lower limits of the cavity, a portion of the posterior surface of the tibia then being broken and crushed. There remained only a small unobliterated space at the upper end which was easily filled with a flap taken from the calf muscles. A similar but smaller cavity on the outer side of the head of the tibia was filled by crushing into it the tubercle of the bone, and inserting a small flap of tibialis anticus to complete the obliteration. In the lower third of the bone no muscle whatever is available for filling a cavity, the only possible method is to bevel down the bone, working over a considerable length, and thus to allow the skin to fall into the cavity.

The Fibula. A radical operation upon the fibula will nearly always take the form of the complete excision of a length of the bone. The fibula, with the exception of its lower third, can be easily dispensed with and any space left is at once obliterated by the peroneal muscles.

The Humerus. The upper end of the humerus is best approached along the anterior border of the deltoid, and a portion of this muscle may be used for filling the cavity. The middle of the shaft of the humerus can be explored along the line of the external intermuscular septum ; if the bone is stripped sub-periosteally the musculo-spiral nerve will escape injury. A portion of the triceps is used to obliterate the cavity, great care being taken in cutting the flap to avoid that part of the muscle which lies immediately over the musculo-spiral groove. The lower end of the humerus is very difficult to explore ; fortunately cavities in this part of the bone are uncommon, sequestra usually being unenclosed and easily removed.

Radius and Ulna. The radius is best explored along its external aspect immediately behind the supinator longus; all except the upper third of the shaft can be approached in this way. The head and the upper third of the shaft should be explored from behind, the supinator brevis not being cut through, but being lifted from the bone from its upper margin. If the muscle fibres are divided, there is risk of injury to the posterior interosseus nerve.

The ulna can be explored along its internal border throughout its whole length between the flexor carpi ulnaris and the extensor carpi ulnaris; owing to the small size of sequestra from the radius and ulna it is seldom necessary to insert muscle flaps in any cavity left during operation.

Other Bones. Chronic osteomyelitis of carpal and tarsal bones will often necessitate the removal of the whole, or of a considerable part of the affected bone. In the carpus the actual excision of one or more of the bones is the best method to adopt to cure a chronic sinus. In the os calcis it may be possible to bevel down a cavity and to fill it with subcutaneous fat; in the other bones of the tarsus such a procedure is seldom possible. On account of the septic complications in the ankle and tarsal joints which often accompany a chronic osteomyelitis of the tarsus, amputation of the foot will often be indicated in these cases. Every case must be considered individually and it is quite impossible to lay down rules of procedure. In the metacarpals and metatarsals, the simple removal of sequestra will usually suffice to cure a chronic sinus.

THE TREATMENT OF DISABILITIES OF JOINTS OF THE UPPER EXTREMITY ABOVE THE WRIST

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THE TREATMENT OF DISABILITIES OF JOINTS OF THE UPPER EXTREMITY ABOVE THE WRIST

Joints of the Upper Limb above the Wrist. The joints of the upper limb are subservient to the functions of the hand in giving it its inherent flexibility, in providing it with as wide and varied a range as possible and imparting stability to its connexion with the trunk. Since strength and flexibility are in some measure antagonistic, the anatomical arrangement is of the nature of a compromise. In considering the effect of gunshot wounds and in attempting to restore the greatest amount of functional activity it is necessary to imitate nature and to make sacrifices, sometimes of strength for the sake of mobility and sometimes the reverse. The problem may be complicated or simplified by the character of the future occupation of the patient. One man will prefer an arm with which he can perform a few simple powerful movements, another will be ready to give up a certain amount of strength to gain capacity of executing finer movements. It follows, therefore, that in some circumstances alternative lines of treatment must be discussed, the final choice of which will depend on the patient's needs.

The Sterno-Clavicular Joint. This joint forms the connexion between the bones of the upper limb and the trunk. Movements of the joint are of chief importance in the more pronounced changes of position of the upper limb, particularly that of elevation of the scapula to carry the arm into the vertical position. In this position the clavicle is brought into its closest apposition to the sternum, and the movement of raising the arm is that which is most likely to cause pain when the joint is affected by arthritis.

Gunshot wounds may cause interference: (*a*) by allowing undue mobility, from destruction or dislocation; (*b*) by limiting movement, from subsequent arthritis or ankylosis. In the former case it is rarely necessary or advisable to interfere surgically. Function is but little prejudiced by undue mobility of this joint, as is seen in long unreduced dislocations of civil practice. In recent cases it is of course advisable to reduce the dislocation, which is easy, and to keep it reduced by a local pad and by fixation of the arm. In dislocations of long standing, such as may be seen after healing of wounds, this is useless, as the ligaments, on which the stability of the joint depends, have been destroyed usually without hope of natural repair. Open operation for fixation, if successful,

will lead to reduction of range of movement and will adversely affect the movements of the whole limb. In a healed case of dislocation, therefore, it is recommended to apply no local treatment but to rely on massage and exercises to restore the best possible function, which will usually be very good. The opposite condition, of ankylosis, will generally need no local treatment. If general treatment does not lead to a satisfying range of movement in the arm, the question of excision of the sterno-clavicular joint must be considered. This is best done by resecting sufficient bone to leave a gap of about ¾ in. and interposing a portion of muscle or fascia between the raw bone surfaces. Massage and exercises may be begun when healing is sound.

The importance of mobility of this joint is well illustrated in Fig. 99 (p. 238), which shows ankylosis of the shoulder-joint, with all abduction movement of the arm dependent on mobility of the sterno-clavicular joint.

The Acromio-Clavicular Joint. The scapula hangs from the end of the clavicle at this joint, which by its movements allows the scapula to maintain the normal relation of the glenoid cavity to the humerus in the changes of position which the latter assumes. In this way the head of the humerus receives strong bony support from behind in thrusting or striking action.

Undue Mobility. The line of the joint runs downward and slightly inward. The acromion is therefore usually dislocated in this direction so that the outer end of the clavicle rises above its normal position in relation to the outline of the shoulder. The joint depends almost entirely in its ligaments for its stability. Reduction of the deformity is therefore easy, but the reduction must be artificially maintained during the process of union of injured parts. In recent cases, when the condition of wounds permits, reduction may be made and kept up by slinging the elbow to the neck, placing pads over the outer end of the clavicle and the tip of the elbow and applying strapping or bandage round the two padded points.

In cases of long standing this procedure is useless. Open operation for fixation is likely to do more harm than good. Massage and exercises are therefore to be used in the expectation of a fairly good functional result.

Ankylosis or Limited Movement. General treatment is usually all that is needed here. It is doubtful whether any operation to provide a false joint would lead to an improvement of function.

The Shoulder-Joint. As is well recognized, the strength of the joint depends almost entirely on that of the muscles which surround it. There is a certain amount of play of the clavicle and scapula in connexion with all movements of the shoulder-joint. This is of especial surgical

importance in abduction movements of the arm from the horizontal to the vertical, which are largely dependent on the mobility of the scapula, which in its turn depends on that of the joints at either end of the clavicle. When the shoulder-joint becomes fixed as the result of injury, the accessory movements of the scapula and clavicle can be made to take its place to the extent of providing a mobile and useful limb.

Since the scapular movements play such an important part in the use of the arm, it may be well to consider briefly scapular injuries before proceeding to the discussion of injuries of the shoulder-joint itself.

Injuries of the Scapula. The scapula may be thrown out of action by paralysis of the muscles controlling its movements, from damage of their nerve supply or perhaps from direct injury. The most important of these muscles are the trapezius, supplied by the spinal accessory and third and fourth cervical nerves, and the serratus magnus, supplied by the posterior thoracic nerve. Paralysis of these muscles leads to a condition of winged scapula with much loss of abduction power of the arm. A shoulder brace should be used to control the scapula and thus to allow a more powerful use of the arm. The nerve injury is treated on the lines indicated elsewhere.

The scapula may be fixed to the ribs as the result of severe injury, in which case arm movements will be limited. Operations to alter this are not as a rule indicated, as, with the scapula in its normal position of rest, abduction of the arm to a right angle is still possible.

Injuries of the Shoulder-Joint. It will be convenient to discuss first the common late effects of gun-shot wounds and their treatment, and afterwards to offer some suggestions as to how these effects may be anticipated and prevented. The late results of gun-shot wounds of the shoulder may be manifest in one of two types of disability:

(1) There may be undue mobility, with want of contact between the humerus and the scapula.
(2) There may be a restriction or complete absence of movement of the joint.

In either case it may be that the best result obtainable will be one of firm ankylosis in the most serviceable position. This position must now be defined.

The Position of Choice. When conditions are such that ankylosis is certain or probable, it is necessary to make sure that this ankylosis will occur in such a position that the best possible use may be made of the movements of the scapula through the acromio-clavicular and sterno-clavicular joints. It is necessary that the arm can be brought down to the side under conditions of rest. The humerus must therefore be fixed to the scapula at the widest possible angle subject to this reservation.

This angle is one of 70 degrees. It is of the greatest importance that this angle should be estimated in the relation of the humerus to the normal vertical position of the scapula and not to the side of the trunk. The vertebral border of the scapula should be vertical when the angle is being estimated. With ankylosis at this angle the arm can be brought to the side, when the lower angle of the scapula is inclined towards the vertebræ, and well above the horizontal when the lower angle is inclined towards the axilla. With the scapula in its normal position the humerus must point somewhat forward as well as outward. The position may be roughly indicated in the normal subject by placing the tip of the middle finger on the most prominent part of the opposite clavicle and raising the elbow nearly to the horizontal. Various splints have been devised to maintain this position. Where there is difficulty in keeping good apposition between the humerus and the scapula, plaster of Paris will usually be necessary and is reliable. It has the additional advantage that it can be made to control the position of the scapula to some extent.

FIG. 79.—Photograph to show disability following excision of upper end of humerus when special treatment has been neglected. Cf. Case III, p. 234, Bugler E.

Undue Mobility. This is practically always the result of an early excision of the head of the humerus following a shattering wound in this region. It is not reasonable to criticize this line of treatment in any given case as it may represent a life saved, or the missile itself may have removed the bone. It is enough to say that the late results as seen in Orthopædic Centres are deplorable. The limb hangs helplessly by the side with practically no power of movement in the shoulder, the usefulness of the forearm and hand is greatly reduced owing to the break in the transmission of power through the shoulder. Passive movements are very free, the deltoid muscle is stretched and wasted, and the humerus can be pushed up towards the socket, from which it drops at once on being released. (Fig. 79.)

Treatment must first be directed to obtaining relaxation of tension on the soft parts, particularly the deltoid, so as to allow of their becoming shortened. The arm must be abducted fully to a right angle and kept in that position, without a break for three months. If the bandolier shoulder-splint (Fig. 80) be used, it will be necessary to reinforce it with adhesive strapping or plaster of Paris, so as to bring the humerus into close approximation with the remains of the glenoid cavity. (See Fig. 97,

FIG. 80.—Bandolier shoulder-splint.

post.) Nothing is so reliable as a plaster of Paris application to maintain both abduction and approximation. It is advisable to cut away some of the plaster to give access to the deltoid for the purpose of electrical stimulation. At the end of three months the result may be tested. If the arm can be held at the horizontal by deltoid action, the case may be considered promising. A splint is reapplied in a slightly less abducted position. If, after a week, the patient can still bring the arm off the splint up to the horizontal, the splint may be lowered further and the test reapplied in another week and so on, until the arm is vertical, when the splint may be abandoned. Even then the splint should still be worn for part of the day until recovery is fully established. If, after any stage of lessening the abduction, it is found that some of the voluntary movement is lost, it is a sign that relaxation is premature and full abduction

should be established for a further period, when the lowering process is repeated. This is known as the ' Clinical Test ' of recovery and is applicable to other parts.

The result is usually less good than that described above. If the patient gains a reasonably useful arm with abduction, say, half-way to the horizontal, this may be thought sufficiently satisfactory and the patient may be discharged to civil life with instructions to apply the splint when possible for some hours each day. Sometimes the procedure will lead to no improvement in three months. Operative treatment is then indicated to promote ankylosis in the position of choice. The site of the joint is exposed. The opposing bones are freshened and also the upper aspect of the shaft of the humerus and the under aspect of the acromion process. The bones are brought into close apposition and fixed by a wire through the humerus and round the top of the acromion. The abduction splint is applied and kept on until union is firm. The arm is then gradually let down, the ' clinical test ' being applied as before described.

Shoulder-Joint with restricted movement or Ankylosis. The causes are extra-articular and intra-articular. Extra-articular causes are most often scar tissue and damage to muscle ; intra-articular a sequel to septic arthritis. Limitation of movement may vary in degree from slight, due to extra-articular adhesions, to complete, due to bony ankylosis. Exact diagnosis is often far from easy, but careful clinical and X-ray examination will give a useful guide to treatment.

The range of movement of the humerus is noted. This may be quite extensive owing to scapular movement, but more usually the arm is stiff in a position of adduction or has only a small range of active or passive abduction.

Gentle passive movements are then applied while the scapula is held as firmly as possible. As this cannot be quite immobilized it is difficult to distinguish bony from fibrous ankylosis, but pain produced by passive movement is strong evidence against the former.

Skiagrams may make the diagnosis clear, showing on the one hand a bony bridge, or on the other irregularity of outline, haziness or narrowing of the joint cavity. In difficult cases it is most important to have a control picture of the healthy joint of the opposite side.

In cases of mere limitation of movement, the character of the limitation is important. If movement in every direction is curtailed the condition is certainly a serious one, probably an arthritis. If any one movement is free or if only one movement is limited, the trouble is clearly less serious and is probably due to extra-articular adhesions. X-rays may again prove helpful or may show very little, even in presence of considerable joint stiffness.

The treatment of ankylosis will be considered first.

Bony Ankylosis. The ankylosis may already be in the position of choice, or at least be such as to allow abduction from the side nearly to the horizontal. In such case the gain by operation may not be thought great enough to justify any interference. This is rarely the case. More usually the fixation has been allowed to take place in a position of too great adduction and operation will be necessary. A cuneiform osteotomy is to be made at the upper end of the humerus through the deltoid. The wedge must be wide enough and placed so as to allow the humerus to be brought up into the position of choice. The limb is fixed on the bandolier splint in fuller abduction from the trunk so as to keep the raw bone surfaces in apposition. This will not exaggerate the abduction from the scapula, which will follow the humerus at 70 degrees from it. Splinting is maintained until union is firm, after which gradual relaxation is allowed.

Fibrous Ankylosis. Attempts to obtain a mobile joint by manipulation or passive movements are to be regarded as useless. Manipulation is of the greatest value, however, in improving the position of fixation from a bad one to the position of choice. The dangers to be guarded against are the lighting up of suppuration and fracture or dislocation of the humerus. There is no certain method of preventing recurrent suppuration, but if wounds have been soundly healed for three months, and if there is no reaction to a test course of heavy massage and radiant heat, the risk may be taken. Fracture is avoided by steadiness of pressure in manipulation and by the application of malleable gutter splints extending over the whole length of the humerus. Dislocation should never occur with proper care.

Ether anæsthesia should be used. An assistant steadies the scapula and presses the head of the humerus upwards from the axilla. The surgeon, standing at the side of the table, grips the upper end of the humerus and applies the front of his forearm along the inner aspect of the shaft and then uses the weight of his body transmitted through his forearm to produce abduction of the patient's arm from the scapula. The movement must be steady and never applied in jerks. In this case abduction should be carried to an angle of 90 degrees from the scapula, and the arm should be fixed at an angle of even greater abduction from the side. There will be a tendency for this angle to be lessened as the scapula 'follows' the humerus to some extent during subsequent treatment. Full abduction is maintained for three months, after which the splint is let down gradually, the clinical test being applied.

If this procedure fails, either in recurrence of adduction or impossibility of abduction, open operation is indicated. Osteotomy is not suitable here as the existing ankylosis is unstable. Arthrodesis, or joint fixation, should be performed on the lines laid down for fixation in cases of undue mobility, at an angle of 70 degrees between humerus and scapula.

Restriction of Movement short of Ankylosis. If movement in all directions is limited, the lesion is probably one of arthritis. The range will then be small, with the greatest loss in abduction. In this case the treatment should be as for fibrous ankylosis. If the position of choice is gained and maintained, the result will probably be a very useful arm, with a small range of movement of the joint in or near the position of choice. If it is found, after trial, that adduction tends to recur, an operation for arthrodesis of the joint should be performed.

In other cases there may be a greater range, possibly with power of abduction from the side nearly to the horizontal. Here massage and active exercises in the gymnasium or curative workshops may be ordered if the wound is soundly healed. A useful limb may result and no operation be needed.

If movement is limited only in certain directions and one or more movements are free the lesion is probably outside the joint. If the wounds are well healed, massage and active movements may be started and continued so long as there is improvement. When this has reached the limit other measures may be considered necessary. There may be some obvious cause of restriction, such as a contracted scar of one of the axillary folds. This should be treated by excision or by gradual stretching on the abduction splint. If full abduction can be obtained passively it should be maintained constantly for three months, when it may be relaxed with the application of the clinical test.

If skiagrams and clinical examination show no clear cause of obstruction, manipulation through a full range may be attempted. The obstruction may yield easily, in which case massage and daily active and passive movements may be used. Passive movements should be applied by the surgeon, and should consist of putting the joint once only through the full range of every movement. It cannot be too strongly emphasized that to-and-fro movements are useless and harmful.

If the obstruction yields with difficulty and with sounds of cracking, or if it is followed by pain and stiffness, the joint must be put at rest in the fullest possible abduction until all signs of inflammation have gone. The abduction splint is then gradually lowered and the clinical test applied. If the limited movement is taking place in the position of choice, massage and exercises will then bring about a good functional result.

Open Operations to mobilize the Shoulder-Joint. No reference has been made to the operations of excision or arthroplasty to provide a mobile joint. These give less useful results as regards function than are obtained by strong ankylosis in the position of choice. Such operations are therefore not recommended.

The Treatment of Recent Gun-shot Injuries. Most of the troubles which

have been discussed might have been avoided by early abduction of the arm with retention in this position until healing is sound. The position of choice should be established as soon as possible and maintained during the healing of the wound, or longer if need be. Stereotyped excision of the head of the humerus may be regarded as a live-saving measure, but it should never be assumed that a good functional result is likely to follow. If operation is necessary only such an amount of bone as will ensure drainage should be removed, as well as any absolutely loose fragments. As soon as the acute sepsis is past, the limb should be fixed in the position of choice. Plaster of Paris, with windows cut to apply dressing, should be applied so as to keep the upper end of the humerus in close proximity to the glenoid cavity. This position is maintained until bony or short fibrous ankylosis results, when with the sterno-clavicular joint as the centre of motion, an almost complete range of abduction or adduction may be obtained.

The abducted position of the shoulder is also indicated in all cases where this movement is likely to be limited either by new bone formation in the neighbourhood of the great tuberosity or by fracture of the acromion process. It also allows relaxation and recovery of a weakened deltoid and prevents contracture of the axillary folds—so common after wounds of the axilla—or general inflammation of the upper limb. In this joint perhaps more than any other, the contracture of scar tissue, which is so often responsible for grave and irreparable deformity, may, in certain cases, if carefully guided, play an important part in the restoration of function.

The Elbow-Joint. The conformation of the articular surfaces of the humero-ulnar joint allows of movement in only the antro-posterior direction. The radio-humeral joint also acts as a pure hinge-joint in movements of the elbow. The superior radio-ulnar joint, because of its communication with the elbow-joint, is necessarily involved in general arthritis of the latter. If the radio-humeral or radio-ulnar joints are ankylosed, pronation and supination movements are not possible. The elbow-joint depends for its stability largely on the co-aptation of the articular surfaces. After some kinds of injury or after excision, the normal bony support is much reduced and the ligaments and muscles then play a leading part in maintaining a degree of stability.

While, in the case of the shoulder-joint, operations to produce ankylosis in the position of choice are believed to give a better functional result than any open operation to produce mobility, this is not true as regards the elbow.

The Position of Choice in Ankylosis. There is no invariable rule for every case. In neglected cases stiffness usually occurs at about 120 degrees and gives a poor functional result. An angle of 100 degrees is

useful in many cases for the right arm of one engaged in clerical duties or for a labourer who has to do heavy work. This position provides a fair reach and will yet enable the patient to get a spoon or fork to the mouth, though with some difficulty. A smaller angle is needed to allow him to brush his hair, and a still smaller one to allow him to fasten a collar or tie. If the smaller angle is chosen the reach is extremely limited.

FIG. 81.—Flail elbow without voluntary control following wide excision.

Excision or Arthroplasty. By excision is meant a carefully planned operation at a quiescent stage and not the emergency operation sometimes done at an early stage with free removal of bone, the end results of which, generally speaking, are deplorable. A successful late excision results in a false joint with a full range of flexion and extension but with a certain amount of lateral movement. It also permits supination and pronation. Function may be good enough to allow of hard manual work, but the strength is not usually equal to that of a normal joint. After arthroplasty, although the final range of movement is often less complete, greater stability is assured. The future requirements of the patient must always receive due consideration. The operative technique will be described later.

The various types of disability seen at a late stage will now be considered.

Excessive Mobility. This is inevitable in many cases from the nature of the injury. The bad functional result of this condition should, however, be kept in mind by the surgeons responsible for the early treatment of these cases. Early wide excision, unless necessary to save life or limb, cannot be too strongly condemned. Thereafter the forearm and hand form a more or less useless appendage, the flexors and extensors of the elbow are stretched and without either power or fulcrum, ligaments are stretched and there is wide flail movement in all directions (Fig. 81). The flail elbow-joint, without voluntary control and with wide separation, is one of the most difficult problems to deal with surgically and often demands fixation by external splintage. In the treatment of this condition an attempt should be made to get the stretched soft parts to retract.

The wrist is slung high to the neck, to relax the flexors, and a figure-of-eight bandage applied to the elbow to bring the bones nearer together. The bandage is removed daily for massage and faradic stimulation, and the patient is encouraged to try to bring his flexors into action. The sling to the neck must be kept on rigorously, without remission for a moment, for two or three months. Return of power may be tested from time to time without letting down the elbow. In some cases there is enough return of power to give hope for the future. At this stage a hinged poroplastic elbow-splint may be fitted, with a block to prevent more than a few degrees of extension. The patient is discharged to some suitable form of occupation. The block to extension may be filed away from time to time as power is regained. If the treatment leads to no recovery of power, the hinged elbow-splint may be used, or an operation undertaken to fix the elbow in a chosen position.

Limited Mobility. This may vary in degree from slight restriction of one movement to complete bony ankylosis. The pathological conditions are very varied. Diagnosis may be easy, as in the case of a contracted scar in the flexure of the joint, but in other cases careful clinical and X-ray examinations must be made. In every case the range of voluntary movement is noted and gentle passive movement is attempted. The joint may be quite fixed but the nature of the resistance may serve to distinguish bony from fibrous ankylosis. In the latter case there will be a certain amount of elasticity, and continued pressure may cause pain. When movement is merely limited, it should be noted if this applies to movements in all directions. If so, there is a serious affection of the joint itself, probably a condition of arthritis. The amount of pronation and supination is an important guide. If these movements are free there is evidently not a general arthritis of the elbow-joint and the trouble is probably extra articular. If either only flexion or only extension is limited, one would expect either a bony block on one aspect or an anchoring adhesion or scar on the other. In the case of the former the resistance is sudden and complete. In the case of the latter it is springy and accompanied by pain. A skiagram will usually clinch the diagnosis. It is often impossible to form a reliable prognosis from X-ray evidence. Sometimes a joint which looks hopeless from X-ray appearance will develop a surprising range of movement (Figs. 82 and 83), others which show very little abnormality may prove very disappointing.

Manipulation as applied to the Elbow-Joint. The elbow-joint holds in certain respects a unique position among the large joints.

Firstly, the disability from ankylosis is very great however well chosen the position of ankylosis may be. It follows from this that choice of position of ankylosis is a matter of compromise. Secondly, the results of manipulation, in obtaining increased mobility, are better on the average

than in other joints. Thirdly, the prospects of excision, in restoring function, are infinitely better than in other joints.

FIGS. 82 and 83.—X-ray and photograph to illustrate range of voluntary control after severe injury to the elbow-joint treated on conservative lines.

These factors will therefore allow greater freedom to test the effects of manipulative treatment without prejudicing unduly the ultimate result, as there is always excision or arthroplasty to fall back upon if the simpler method fails. The chief object of manipulation is to re-establish a right of way to full flexion. Recurrent suppuration may be avoided by using preliminary tests with deep massage and radiant heat

as previously described. Fracture of the arm or forearm bones is prevented by application of gutter splints before manipulation is undertaken. There is still danger of fracture of the olecranon, which can only be prevented by knowing when to stop in the face of strong resistance to movement. While the patient lies on his back, under full ether anæsthesia, the operator stands on the right side, in the case of the right elbow, and grips the forearm at its upper and middle parts. The arm must be well supported on a sand-bag. The operator then inclines the weight of his body steadily on the forearm so as to make flexion of the elbow. Much bony grating or great resistance is a warning to proceed carefully, and if only a slight movement is obtained it is well to stop and consider other methods. If the case is a suitable one the joint will yield with comparative ease into full flexion, that is, an angle of about 40 degrees between humerus and forearm bones. If supination is lacking, this should be obtained at the same time. The wrist is slung to the neck in full flexion and supination (Fig. 84).

FIG. 84.—Photograph to illustrate use of Thomas collar and cuff to maintain flexion of elbow.

Rest is maintained in this position until all inflammatory reaction has subsided. At the end of about a week the sling is slightly relaxed to allow a few degrees of extension. The patient is encouraged to attempt active movement through the small range allowed. If, after a few days, this is free, a further relaxation is allowed, giving a larger range of movement. This procedure is followed until up-and-down movement as far as the right-angled position is possible. The sling is then left off and exercises ordered. Active movement of the joint and the force of gravity will then both tend further to increase the range. If after any relaxation the range of movement becomes reduced, it is a sign that movement has been premature and the joint must again be fixed at rest in full flexion. This is the clinical test as applied to the elbow-joint. Failure after manipulation is often due to its being disregarded.

The Turner Splint. In cases which do not lend themselves to forcible manipulation increase of movement may sometimes be made by gradual

splintage. For this the Turner splint (Figs. 85 and 86) is most useful. This consists of arm and forearm pieces connected by a screw adjustment. The pieces are separately incorporated in plaster of Paris. The upper bandages encircle the arm from the axilla to the elbow; the lower surround the forearm from the elbow to the dorsiflexed wrist. It is important that the plasters should have these bearings above and below so as to prevent slipping. After the splint is applied the angle at the elbow is very gradually adjusted daily by small changes into greater flexion or extension. It is the method of choice in increasing extension in many cases, as manipulation is of little use.

The application of the methods of treatment to the different disabilities will now be considered.

Bony Ankylosis. If the angle of fixation is 100 degrees or one which suits the patient's needs, he is offered a choice of having no operation done or submitting to excision or arthroplasty, after their merits and demerits have been laid before him. If the angle is unsatisfactory, there is the additional choice of obtaining a chosen position by wedge-shaped osteotomy. It seems right to apply reasonable pressure in favour of operation for mobilization.

Fibrous Ankylosis. The joint is usually fixed at about 120 degrees. Manipulation into full flexion is generally advisable, the clinical test of gradual relaxation being subsequently applied. If stiffness persists, the forearm, acted on by gravity, can be allowed gradually to sink down to the position of choice and is then fixed in a semi-permanent splint, or a mobilizing operation may be undertaken. If the joint yields to manipulation but slightly, the Turner splint may be tried. If it yields not at all, the treatment will be as for bony ankylosis.

A Limited Range of Movement. Here one must proceed with caution as much may be lost by incorrect treatment. If wounds are soundly healed, massage and active exercises may be tried for perhaps a month. So long as improvement is obtained, no other treatment is necessary. If there is no improvement, flexion of the joint should be obtained if possible either by the Turner splint or by manipulation, so that the range of movement obtained may be in the position most useful to the patient.

Fixation or limitation of movement may be functional in character and simulate the conditions we have described. For the diagnosis and treatment of this condition the reader is referred to another chapter (p. 241).

Conditions such as bony block or contracted scar require special treatment.

Bony Block. This may be due to imperfect reduction of fracture, detachment of fragments of bone, myositis ossificans or unreduced dislocation. In the case of myositis ossificans it is essential that nothing operative be done until the process has come to a standstill, otherwise recurrence

is inevitable. The brachialis anticus is most frequently affected. The elbow should be slung in as full flexion as the block permits so as to set

FIGS. 85 and 86.—Photographs to illustrate Turner splint and its application to promote extension of the elbow.

the muscles at rest and to apply pressure against the bony mass. Only after the outline by X-ray becomes clean cut should excision of the mass be attempted. Rest alone may give a satisfactory result.

The front of the lower end of the humerus is the usual site for other types of bony block. They may be removed by the chisel after stripping the brachialis anticus from the humerus. It is advisable to lay a piece of fascia lata from the thigh over the remaining raw surface of bone to act as a limiting membrane. The joint is put up in full flexion until healing is sound, after which gradual relaxation is allowed, the clinical test being applied.

Contracted Scar. This is a common cause of limitation of extension of the elbow. It may be possible to extend the elbow passively to the full extent but it springs up into semi-flexion at once when released and full active extension is not possible., The condition may be treated by gradual stretching or by excision of the scar. If the method of gradual stretching is chosen, the elbow is extended at once, or if this is not possible the Turner or other splint must be used. When the limb has been fully extended, it should be kept in this position for at least three months, to allow time for the contracting scar to draw on surrounding skin. At the end of this period the splint may be left off intermittently but careful observation must be kept. Loss of full voluntary extension is a sign that a longer period of continuous extension is required.

Excision of the scar will often save time. It may be possible to bring healthy skin together to close the wound or a simple plastic operation may suffice, a flap being brought across from one side of the joint. In more severe cases a flap from the abdomen gives very satisfactory results. After complete removal of the scar, the elbow is brought to the abdomen in what will be a comfortable position for the patient and the site of the flap selected so that no tension will result at the end of the operation. A generous flap is cut and turned upward from the abdomen. It should include all layers down to the aponeurosis. The flap must have a wide base. The free edge of the flap is then sewn as far as possible round the edges of the wound of the elbow. The wound of the abdomen is easily closed. The wrist is slung to the neck with the arm and forearm firmly bandaged to the body to prevent movement. At the end of a month the base of the flap is divided by stages under local anæsthesia. This helps to ensure its vitality. When the arm is free the suturing is completed and the limb splinted in full extension for a week or two. Free use may then be allowed. Usually there is no tendency to recurrence of flexion contracture.

The Operation for Excision of the Elbow-Joint. This operation is frequently necessary in the early treatment of gun-shot injuries, but when it is undertaken for the purpose of restoring function to the joint it should be performed only in the stage of quiescence, when all inflammation has long subsided, as it is essential that the decision as to the amount of bone to be removed should not be hampered by the presence of septic foci

or necrotic bone. The posterior incision is convenient, and the joint is exposed in the usual fashion. The upper saw cut should pass through the tips of the epicondyles and it is recommended that the cut should be made obliquely, so that the surface for articulation is narrow from front to back, while the maximum width is preserved. The lower cut just includes the articular surfaces of the radius and ulna which enter into the elbow-joint proper. If, as is usually the case, the superior radio-ulnar joint is ankylosed, this joint is to be excised separately with bone forceps without shortening further the radius and ulna. It is a bad practice to include this joint in the main transverse section of the radius and ulna, as too large a gap will then be left between these bones and the humerus.

The limb is splinted in full extension and supination for a week, and is then fixed in full flexion and supination by a sling from the wrist to the neck.

When healing is sound full flexion is relaxed little by little with the use of the clinical test as previously described.

Arthroplasty of the Elbow. The joint may be exposed by a posterior incision. It is not necessary to deliver the ends of the bones from the wound as far as in excision, but all soft parts must be stripped aside from the posterior aspect of the joint, all adhesions must be fully broken down and the joint surfaces levered apart. It should be noted that all ligaments are necessarily shortened after destruction of cartilages and approximation of the ends of the bones, so that the operation must, to be satisfactory, leave a potential space.

The roughened surfaces are therefore trimmed to leave a space of about a quarter of an inch between the articulating bones. The radio-ulnar joint receives similar treatment.

A flap of fascia lata, 8 in. by 4 in., is next cut from the front of the thigh. While it is still lying on its muscular bed, a separate catgut suture is passed through the middle of the edge of each long side of the flap and tied, one end of each suture being cut short. The flap is then raised by the sutures and forms a double curtain of fascia 4 in. square. Straight cutting-needles are threaded with the sutures and passed into the back of the open joint and out in front, one near each side. The free ends in front are drawn on, and this pulls the double fascia flap home into place between the raw bone surfaces. The ends of catgut are tied together across the skin in front of the joint. The double fascial flap is then carefully arranged to cover the raw bone surfaces, pains being taken to insert a portion between the radius and ulna. The triceps and its extension are next sewn across the back of the joint and the skin wound is closed. The wrist is slung to the neck with the elbow-joint in full flexion. At the end of three weeks gradual relaxation from full flexion

is begun with the use of the clinical test. Massage and faradism may be begun at this time. Passive movements are not advised.

Pronation and Supination. These movements involve the radio-humeral, the superior radio-ulnar, and the inferior radio-ulnar joints.

FIG. 87.—Photograph to illustrate difficulty in writing when ankylosis of right forearm has taken place in the fully supinated position.

Arthritis of the elbow will certainly interfere with them, but arthritis of the wrist may or may not according to whether the inferior radio-ulnar joint is involved or not. Mal-union of fractures of the bones of the forearm may also interfere with the movements of pronation and supination. The treatment of fracture of the forearm is outside the scope of

this chapter, but it is necessary to emphasize the importance of maintaining full supination in their treatment in order to avoid cross union. The treatment of the joints into which the upper end of the radius enters is bound up with treatment of disabilities of the elbow-joint. The loss of supination forms an additional inducement in favour of operation for ankylosis of the elbow-joint.

The condition of the inferior radio-ulnar joint is of importance in dealing with injuries of the wrist. If there is ankylosis in bad position an attempt should be made to correct this by excision or arthroplasty, when the wrist is being treated. If the inferior radio-ulnar joint is unaffected special care must be directed towards keeping it intact during the operation on the wrist. For this reason it is necessary to confine the operative procedure on the wrist to the radial aspect of the joint.

Operations to mobilize either radio-ulnar joint cannot be relied upon to result in mobility and, if fixation threatens to recur, care should be taken that the position best suited to the patient is obtained.

Although during treatment full supination is excellent, it is not always the position of choice where ankylosis results. As a rule the best position for ankylosis is midway between pronation and supination, so that on flexing the elbow the back of the thumb is brought to the mouth. In the case of a clerk the position of the hand in writing, that is with a few degrees more pronation, will usually be preferred for the right hand. The supinated position is very awkward for writing, as shown in Fig. 87.

Where limited movement results, the position of supination should be maintained for a longer period, as there is a natural tendency for pronation to occur. If the forearm is already in the position of pronation, methods of gradual correction may be used to regain the supine position.

When supination is well established, Morton's supination splint (Fig. 88) may be used to maintain this until there is no tendency to recurrence. This splint may be removed daily for massage and active movements.

The Treatment of Recent Injuries. The late conditions which are found and the methods of dealing with them will indicate the procedure to be used when possible at early stages. The essential treatment, often for some months, is rest, and the position of rest must be dictated in the first place by the condition of the wounds, their position, the amount of sepsis, and the extent of damage to bony structures. In the graver injuries full extension and fixation in the Thomas arm-splint (Fig. 89) is commonly used until the acute sepsis has been controlled or the fracture has begun to show signs of union, when the elbow should be gradually flexed. Supination should be assured from the beginning. The duration of the fully extended position should not exceed one month. The result

of too long fixation in extension is shown in Fig. 90, where complete ankylosis in full extension is present. If the fully flexed position in supination can be obtained and maintained until the conditions demanding

Fig. 88.—Morton's supination splint

Fig. 89.—Photograph to illustrate the use of the Thomas arm-splint at the early stage in severe wounds of the upper extremity.

rest no longer exist, a large number of cases will not require such prolonged treatment in hospital in this country. Cases with pronation of the forearm and limitation of flexion at the elbow are so common that every effort should be made as soon as possible to guard against these conditions. After full flexion of the elbow-joint and supination are secured,

gravity and function will both tend to increase any movement which results.

The Surgery of Nerves in relation to Joints of the Upper Extremity. Gun-shot wounds often result in the loss or destruction of several inches of the main nerves, and the possibility of suture is frequently dependent

FIG. 90.—Photograph to illustrate ankylosis of elbow in extension with full pronation of forearm : points to be guarded against in prolonged treatment in the Thomas arm-splint.

on our being able to maintain the necessary relaxation by posture of the joints of the limb. The positions usually required are flexion of the wrist and elbow with or without pronation of the forearm, and adduction of the shoulder. These positions, if possible, should be obtained before suture of the nerves is undertaken, and if present they should not be altered until this is assured. Where it has not been possible to obtain close approximation of the nerve ends there still remains nerve crossing,

nerve grafting, or tendon transplantation. Personal experience of the first two has been unfavourable, and reliance is placed entirely on the last. One of the most important factors of success in tendon transplantation is a freely movable condition of the joints directly affected. For successful tendon transplantation we must have strong healthy muscles, and these

FIG. 91.—*Case I.* X-ray showing new bone formation following excision of the elbow where early massage and passive motion started on the seventh day.

will only be available if the joints they control have permitted their free use.

The following cases serve to illustrate some of the principles which have been emphasized.

Illustrative Cases.

Case I. Pte. J. R., Grenadier Guards.

G.S.W. Right elbow, October 7, 1915.

June 5, 1916. Elbow-joint excised.—In splint for two weeks; sling

five weeks.—Massage and passive movements begun seven days after operation.

Condition on admission: August 12, 1916. (Fig. 91.) 20 degrees passive movement at an angle of 140 degrees.—Pain in forcing movement.

X-ray shows new bone formation in front of joint.

August 16, 1916. Elbow flexed to 48 degrees under anæsthetic.

Collar and cuff applied.

FIG. 92.—*Case I.* Shows movement obtained after fixation of this case in fully flexed position.

October 4, 1916. Has 15 degrees movement to acute flexion.

Arm to be gradually dropped.

November 30, 1916. Photos showing movement on discharge, November 20, 1916 (Fig. 92).

Case II. Pte. P.

Shrapnel wound left elbow, December 12, 1916.—Four operations for removal of bone.

April 2, 1917. Condition on admission: discharging sinus.—Fusiform swelling of joint.—Arm held with elbow at angle of 160 degrees.—Has 45 degrees passive movement; no voluntary control.—Forearm in pronation.—Attempt to supinate painful.—Unable to dorsiflex wrist.—Fingers rigid. (Fig. 93.)

Treatment: gradual supination of forearm and flexion of elbow with Jones's elbow-splint, with wrist gradually dorsiflexed on short cock-up splint. (Fig. 94.)

FIG. 93.—*Case II.* Condition of elbow four months after severe gun-shot wound.

December 3, 1917. Photo shows voluntary movement obtained (Fig. 95).

Case III. Bugler E., 1st A.I.F.

G.S.W. Left shoulder, September 14, 1916.

November 7, 1916. X-ray shows condition on admission (Fig. 96).

FIG. 94.—*Case II.* Showing use of Jones's elbow-splint to flex elbow gradually and supinate forearm.

FIG. 95.—*Case II.* Showing range of movement obtained eight months after admission.

FIG. 96.—*Case III.* X-ray showing absence of upper end of humerus seven weeks after severe injury to left shoulder.—Note adducted position.—Presence of sequestra.

FIG. 97.—*Case III.* Showing plaster fixation in the position of choice with window for dressing.

FIG. 98.—*Case III.* X-ray showing ankylosis of scapula and humerus.

Much swelling and pain, and discharging sinus.—No involvement of main nerves.

FIG. 99.—*Case III.* Shows range of movement obtained one year after admission.

November 25, 1916. Arm fixed in abduction ; plaster of Paris with window for dressings. (Fig. 97.)

January 11, 1917. Removal of sequestra.

X-ray shows position of ankylosis obtained (Fig. 98).

October 8, 1917. Photo shows range of movement obtained (Fig. 99).

ORTHOPÆDIC SURGERY OF THE HAND AND WRIST

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ORTHOPÆDIC SURGERY OF THE HAND AND WRIST

FOREWORD

In this article surgery of the hand and wrist will be dealt with primarily from the standpoint of function. No criterion other than function can be of the slightest interest to the patient applying for relief. In no other part of the body is it more important that surgery should be viewed more carefully from the standpoint of future use than in the region of the hand and wrist. When we consider earning capacity and economic value, the greater part of all members of society are more affected by disabilities of the hand than in other parts of the body, unless we except brain and special sense. In the case of the small group of individuals whose earning capacity and value to the community is not materially affected by hand disabilities, the daily annoyance in ordinary life should be sufficient to enlist the effort of all surgeons toward their relief.

Surgery of the hand, where the object is the repair of extensive injury, can only be successful when the question of function is at all times the first consideration. This viewpoint will save many errors of judgement which would condemn to failure an operation technically beyond criticism. For example, it would be futile to attempt extensive freeing from scar or suture of tendons on the back of the hand or palm in the presence of marked stiffness in the finger-joints which those tendons govern. The joint condition would preclude early movement of the tendons to prevent their re-adherence. The joints should always be mobilized before the tendon operation is ever attempted.

The orthopædic viewpoint of function demands that the surgeon at the very outset place the hand or finger in its most useful position, should the very worst happen. Appreciation of this principle will do much to lessen the disability which, in some hand injuries, will be quite inevitable. It will save months of the patient's time from tedious treatment which will be necessary to correct a wholly preventible disability.

The position for function of the hand is obviously the position of grasp. The attitude naturally assumed by the hand grasping a water-glass is a safe criterion for position in which a hand may be placed during convalescence from injury. In this position the wrist is dorsiflexed 35–40°. The thumb is almost completely abducted and rotated in the position of apposition to the other fingers. There is enough flexion at the basal thumb-joint (carpo-metacarpal) to bring the plane of thumb and index

metacarpals about 50° forward from the plane of the palm. The fingers are slightly flexed at the metacarpo-phalangeal joints. In this connexion it should be recalled that rarely or ever is it justifiable to have these joints completely extended. The likelihood of recurvate or hyperextended knuckles to follow any hand injury should always be borne in mind, and effective measures taken to prevent a deformity so obstinate and difficult to treat. The same is true of the inter-phalangeal joints. An effective splint favouring a few degrees of flexion will obviate this difficulty.

Operative surgery of the hand, and particularly of the palm, still leaves great room for improvement in present methods. Its present unsatisfactory state must be realized by all surgeons who have attempted removal of palmar scars or fascial contractures. Important tendons, nerve branches, and other structures are in such close relation that reforming of scar and adhesions is more than likely.

One often sees the disability following suture of cut tendons in the palm to be quite as great as before the operation—the result of reforming adhesions. This condition must be traceable to faulty methods. The trauma of handling the tissues must be reduced to the minimum. Probably one of the greatest factors in traumatization is the sponging with gauze. The great progress made in surgery of the knee-joint by use of the tourniquet and the avoidance of all sponging and traumatization of joint synoviæ should be applied to hand surgery as well. Tendon synoviæ are quite as susceptible to the injuries of handling, and the area is more vascular than the knee-joint. The use of the tourniquet in the arm undoubtedly carries more hazard than in the thigh, but careful use should make it a safe procedure. The axillary tourniquet crossing over the clavicle after making its pressure on a pad in the axilla has been suggested by Osgood. The pneumatic tourniquet, relaxed at intervals, seems safe over the biceps and is worthy of a more general trial. A bloodless field for hand surgery will greatly reduce the time of operations, too frequently long and tedious. The great importance of a very firm even bandage after all operations under tourniquet must not be forgotten.

The consideration of future function following tendon operations in the hand will always demand early movement of that tendon to prevent its becoming adherent. This procedure can do no harm, for in a properly sutured tendon there should be no question of separation of the two ends. A Lange stitch, or better, that of Kanavel, makes separation quite improbable and allows movement to take place a week after operation. Should voluntary movements be difficult the electric current can be utilized over the belly of the muscle and its antagonists.

Very often hand wounds or injuries of civil life simultaneously represent damage to bone, joint, nerve, and tendon, or any combination of

these. In such cases the result of operative treatment will be wholly dependent, not upon the technical skill with which the operation was done, but upon the judgement displayed in forming the operative plan. The two-stage operation offers great advantages. It removes the temptation from the surgeon to do at one operation a nerve suture (the after-treatment of which requires rest) in the field of a joint operation which demands mobility for its successful after-treatment. Obviously bone grafts and near-by tendon operations do not belong together for the same reason.

In many instances hand injuries require a very careful preparatory treatment before any cutting operation is permissible. Heavy massage and hot baths are very useful in detecting a merely quiescent infection before a repair operation is attempted. Stiff joints should be mobilized and the skin carefully prepared as a preliminary measure to an operation in which the strictest asepsis is an essential.

COLLES'S FRACTURE

Colles's fracture is one of the most frequently met with in the entire body. Fracture of the clavicle alone seems to compare with it in frequency. It is quite uncommon in children but is often seen in elderly people, particularly women, as the result of a fall upon the pronated and extended hand.

Typically, the radius is fractured about 1 in. above its carpal end. The styloid process of the ulna is frequently fractured at the same time. Dissections have proven that the triangular fibro-cartilage may be ruptured by the separation of the radius and ulna. The lower end of the ulna is usually prominent, as a result of the backward displacement and rotation of the lower fragment. The hand shows radial deviation and the classical ' dinner-fork deformity '.

Impaction or strong engagement of the fragments may occur to render reduction more difficult.

In most complete fractures there is serious derangement of the true axis of the wrist-joint, and the tendons on the dorsum of the wrist are displaced from their normal grooves. Failure to restore normal relations by accurate reduction will in this way produce marked disability in later use of hand and wrist.

The mobility of the hand is markedly interfered with. Voluntary rotation is slight or absent, and flexion of the wrist as well as hyperextension are both inhibited. Lateral mobility is sharply restricted.

Pain is a prominent symptom, usually referred to the internal aspect of the wrist. A marked tenderness is complained of in the region of the internal lateral ligament. In fractures even without great displacement, tenderness over the fracture line of the radius can be easily demonstrated.

The same is true with fracture of the styloid of the ulna. Crepitus may be readily felt but in many cases is absent. Rough methods employed to demonstrate this sign are quite unjustifiable. The swelling varies much in its extent. Synovitis of the wrist-joint is occasionally seen but should clear up by the time union has occurred.

Treatment. For reduction we have used the manœuvre advocated by Sir Robert Jones as offering strongest mechanical advantages for control of the short radial fragment. He is quoted and his illustrations appear herewith.

To reduce a left Colles fracture, the surgeon takes the patient's arm in his left hand, with his own scaphoid tubercle against the projecting

FIG. 100.—Colles's fracture. Manual reduction of deformity.

lower end of the fractured radial shaft ; he then places his right hand on the dorsum of the patient's wrist with his own scaphoid on the projecting lower radial fragment (Fig. 100). A firm grip with a slight traction and twist of the wrist completely reduces the deformity. It does not require great strength.

The anterior aspect of the radius has a distinct concavity at its lower end, and the anterior inferior margin projects considerably. If this curve is restored, reduction is complete.

The fragments can be retained in position by slight pressure of finger and thumb, one on the flexor surface of the upper fragment just above the seat of fracture, and the other on the dorsum of the wrist-joint and styloid process to prevent it from rotating backwards and outwards.

The tendency for the deformity to recur is not great if the reduction is complete, therefore the fracture is put up by placing a pad of wool or felt on each of these two points, retaining them in place with splints (Fig. 101).

FIG. 101.—Colles's fracture, application of pads and splints

FIG. 102.—Colles's fracture splints.

The splints most useful are the thin metal gutter-splints to which a slight spiral twist has been added to maintain pronation of the hand (Fig. 102).

The dorsal splint extends from the middle of the metacarpals to the elbow. The ventral or anterior splint reaches from the elbow to the thenar eminence. Adhesive strapping will hold the splints firmly together

and the pads in their proper place. The spiral twist of the posterior or dorsal splint prevents return of rotatory deformity (Fig. 103). The fingers are left free since the play of their tendons over the seat of the fracture cannot do harm after complete reduction has been obtained. The forearm is slung at a right angle.

No movement should be allowed for three or four weeks while there is a possibility of straining the newly formed callus. Disability and union in deformity following Colles's fracture can almost always

FIG. 103.—Colles's fracture put up.

be ascribed to incomplete reduction, or loss of it, by too early movement and use of the hand. This indiscretion may be followed by pain and swelling in the whole wrist, and may require several weeks for return to normal. The anterior splint may be retained while the patient accustoms the wrist to ordinary use.

Warm baths and massage are of great help after the removal of the splints.

Old cases of mal-union will require refracture under anæsthesia by use of the Thomas wrench applied as in Figs. 104, 105. After breaking down the union, the reduction is done as in the ordinary recent case. The utmost care is necessary to keep the splints and pads accurately adjusted to avoid the tendency for recurring of the old deformity.

Vigorous massage and hydrotherapy may be needed to clear up stiffness of the fingers, but must not be used early enough to endanger position of the fragments.

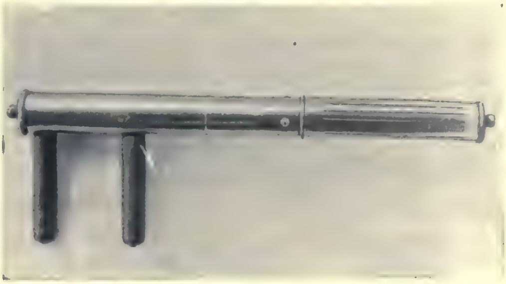


FIG. 104.—Thomas's wrench.

FIG. 105.—Colles's fracture, Thomas's wrench applied.

LESIONS OF THE RADIO-CARPAL JOINT

Lesions of the radio-carpal joint as a result of gunshot wounds show a varied pathology according to the direction of the wound, the severity of the infection accompanying it, and the amount of soft part injury to near-by tendons and nerves.

The treatment at the outset must, of course, be directed mainly toward the early clearing up of the infection so as to limit the destructive

processes always attendant upon any purulent arthritis. The efficient drainage of the joint at all times will limit the duration of the infection to a minimum and reduce the amount of the cartilage loss. By this means the surgeons treating the wounds early will leave to the reconstructing surgeon the best chance of obtaining the most useful hand possible following such an injury. Indeed, with even extensive wounds of the wrist-joint, where the surgeon has availed himself of the least destructive avenues of wrist-joint approach for drainage, the later results of treatment for restoration of function are surprisingly good.

The Ollier paratendinous incisions or the Kocher dorso-ulnar incision for wrist-joint drainage give surprisingly good drainage of the joint with minimum of damage to soft parts. If the forearm is fully supinated, gravity assists drainage and minimizes the possibility of the serious consequences following drainage of the joint from the flexor surface. Ventral incisions of the wrist-joint are always to be avoided and when present should be allowed to heal at the earliest opportunity. Drainage should be continued through the dorsal incisions until the infection is wholly controlled.

Nowhere in the body is an appreciation of proper position of the joint in view of later function more important than in the wrist. For this reason efficient and constant traction of the hand should be instituted by taking pull from the fingers and thumb, or as much of the hand itself as the wound will allow. Flexion of the wrist, so liable to occur without active preventive measures, must not be allowed. Dorsiflexion to about 30° should be sought. By these measures the nearest approach to actual separation of the infected wrist-joint surfaces is obtained, and the stretch of the tendons discourages movement and spread of infection along their sheaths.

To obtain this traction various methods must be employed according to the size and situation of the wounds. The forearm finger traction splint shown in Fig. 112 is only adaptable to very small wounds on the dorsum. In the greater number of wrist wounds, the Thomas arm-splint may easily be adapted by bending at the elbow and spreading the side bars around the hand in the shape of a tennis racquet. A slight bend of the splint at the wrist easily gives dorsiflexion by adjustment of the flannel strips. This splint has the advantage of easy access to extensive wounds and is not difficult to procure. Plaster-of-Paris splints with metal bar attachments for traction will offer advantages in individual cases (Fig. 113).

Healed Wounds following Wrist-joint lesions seen late at orthopædic centres present problems for restoration of function which may be traceable either to the injury of the radio-carpal joint itself, the soft parts about it, or to the near-by inferior radio-ulnar joint.

While very many wrist-joint deformities are preventable with proper care, undoubtedly many cases present such difficulties in treatment that later measures for correction are inevitable.

The prognosis of stiffness in the wrist-joint is dependent upon the amount of destruction which has occurred to the cartilage on the articular surfaces of the radius and the carpus itself. Where actual bony ankylosis has occurred with the wrist in approximately 30° of hyperextension, surprisingly good function results with strong power of grasp. In all cases, therefore, whether or not ankylosis is likely to occur, this position should be maintained and any tendency to radial or ulnar lateral deviation avoided.

In healed ankylosed wrists of less than 30° of hyperextension, corrective measures to restore the functioning position are clearly indicated. Whether the measure to be adopted be operative through Kocher's dorso-ulnar incision (Fig. 106) or by manipulation under anæsthesia is dependent upon the surgeon's individual preference.

The time interval following the healing and the history of the original infection must also be determining factors as to the proper time for this procedure. Wrists ankylosed in even the straight position (without flexion) demand replacement to the dorsiflexed position, particularly if it be the right hand. Writing with the wrist in mid position ankylosis is most difficult, since the forearm cannot rest upon the table with the fingers flexed.

ARTHROPLASTY OF THE WRIST-JOINT AND HAND

Wrist-joint injuries ending in bony ankylosis in good position bring up the question of the propriety of arthroplasty.

In our experience most patients who have a fixed wrist in 30–35° of hyperextension with free rotation are usually quite satisfied with their hand. If the rotation is not free it may be restored by a simple operation outlined below. For a labouring man we are convinced that the condition just outlined is preferable to anything he could reasonably expect from wrist arthroplasty at this time. Any patient must realize that for mobility in the joint they must give up a certain amount of power and stability.

For the patient whose work does not involve heavy use of the hand, arthroplasty is justifiable.

A reasonable arc of mobility may be expected from the operation.

There is great difference of opinion as to the interposing material to be used, with perhaps the greatest number favouring fresh grafts of fascia lata of the thigh. We have come to believe that failure or success of arthroplasty is not dependent upon the interposing material. In fact we have had quite as good results without its use.

Probably a very important factor is the careful handling of the soft tissues about the joint during the operation, and the avoidance of leaving periosteal shreds about the operative field. The minimal amount of tissue handling and sponging decreases the local reaction which is always to be avoided.

Sufficient bone should be removed to allow free movement without bony grating. We can recommend the Jones method of 'hammering'

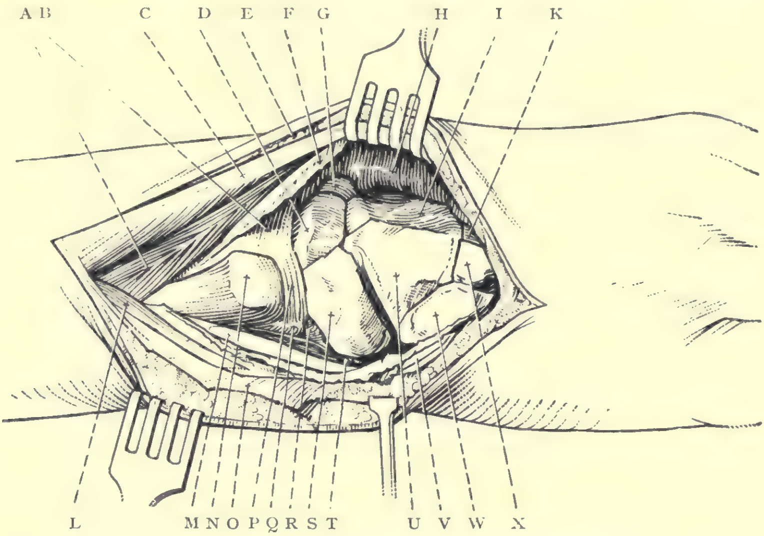


FIG. 106.—(After Burghard.) The Kocher dorso-ulnar incision for approach to the wrist-joint and carpus. A, Extensor indicis ; B, Radius ; C, Extensor digitorum communis ; D, Semilunar ; E, O, Posterior annular ligament ; F, H, Periosteal and dorsal ligaments ; G. Scaphoid ; I, Os magnum ; K, Base of the third metacarpal ; L, V, Extensor minimi digiti ; M, Extensor carpi ulnaris ; N, Head of the ulna ; P, Triangular cartilage ; Q, Styloid process ; R, Internal lateral ligament ; S, Cuneiform ; T, Pisiform ; U, Unciform ; W, Base of the fifth metacarpal ; X, Base of the fourth metacarpal.

cancellous bone ends to produce 'bone scar'. There seems to be little question that this procedure decreases the tendency to bone proliferation.

We feel that more arthroplastic operations of the upper limb have been ruined by their post-operative treatment than by their operative method. Too much stress cannot be laid on the point that the spacing between the raw bone ends must be maintained throughout the period of healing. The only efficient method of maintaining the spacing is by fixed steady traction. Its efficiency should be tested by X-ray. The immobilization that traction gives will favour the earliest disappearance of the post-operative swelling. It may be discontinued when the forma-

tion of the fibrous hinge between the two bones is complete. This will be guarantee enough that union of the bones should not occur.

Arthroplasties of the fingers at the metacarpo-phalangeal and interphalangeal joints may be done with a very fair chance of success. The same principles apply.

It is well to remember that in metacarpo-phalangeal arthroplastics the greater amount of bone should be taken from the phalanx rather than from the metacarpal. This is due to the fact that loss of substance in the metacarpal gives a retracted knuckle which in itself will inhibit flexion of the joint. Here also traction should be a part of the post-operative treatment.

LESIONS OF INFERIOR RADIO-ULNAR JOINT

The statement that wrist-joint bony ankylosis in the properly hyper-extended position brings only a moderate inconvenience must be modified to a certain extent. With such ankylosis a movable inferior radio-ulnar joint is of prime importance, because loss of forearm rotation is very disabling even without the wrist-joint stiffness.

Where **involvement of the inferior radio-ulnar joint** leaves stiffness or even ankylosis as a probable result, the forearm should never be maintained in either the fully pronated or fully supinated position. In the former position elbow flexion would present only the back of the hand to the mouth, and in the latter the patient would be utterly unable to pick up the smallest object from a flat surface. The one position is quite as vicious as the other. The mid-position is also unsatisfactory, as writing and many other movements are difficult.

Probably the most useful position for a non-rotating forearm to be fixed is at 35° of pronation from the mid-position. This position allows writing, movements of grasp, and eating.

This functioning position of forearm rotation should be maintained in all lesions below the elbow which may later endanger the movements of the radius about the ulna.

Where loss of forearm rotation has resulted from lesions about the wrist, a most satisfactory and simple operative procedure has in our hands given a complete range of mobility. In a small series of such cases the author has exsected a small bit of the lower end of the shaft of the ulna.

Author's Operation. An incision is made upward from the wrist-joint, 2 in. long, over the subcutaneous border of the ulna in the interval between flexor and extensor carpi ulnaris tendons. The pronatus quadratus muscle is thus exposed and lifted from part of its insertion on the ulna, *without* disturbing its periosteum. By means of a Gigli saw, slightly more than a quarter of an inch of the ulna is removed from just above its head. No shreds of periosteum should be left in the interval or on

either end of the ulna. A muscle flap from the flexor carpi ulnaris muscle near by may be thrown into the interval. The fleshy belly of the flexor carpi ulnaris or a bit of the pronator quadratus may be used. After ordinary closure of the wound a simple splint is applied for a few days, and then motion allowed when wound healing is firm.

Our results from this operation have been uniformly satisfactory as regards completely restoring the arc of rotation (Fig. 107, A, B, C, and D).

This procedure has also been employed independently by Colonel DeCourcy Wheeler of Dublin.

We prefer this removal of a section of the ulnar shaft at its lowermost end to the method of removal of part or all of ulnar head because it avoids the deformity of the narrowed wrist and leaves intact the groove on the dorsal surface of the ulnar head for guidance of the extensor carpi ulnaris tendon. Furthermore, it is done in the area where infection has not existed, and it obviates the possibility of painful impingement of the lower end of the ulna against the flaring lower end of the radius. We have seen no tendency toward the recurrence of the limitation to rotation, nor is there ulnar lateral deviation of the hand. The added usefulness of the hand, particularly with ankylosis of the radio-carpal joint, far outweighs any possible weakening of the grip. The latter, if present, is almost inappreciable. Large amounts of ulna should not be removed because the lower end of the ulnar shaft would tend to dislocate on the dorsum.

Fibrous adhesions producing Wrist Stiffness. Where lesions of the wrist-joint have not destroyed sufficient cartilage to produce a bony ankylosis but where stiffness is present from adhesions of varying degrees of severity, the problem of restoring function is much simpler. The wrist-joint lends itself most easily to restoration of mobility even though the adhesions are dense. Our experience has been more fortunate with the conservative method of constant pressure of the wrist into dorsiflexion than with the ether manipulation, which is employed by some surgeons. Immediate dorsiflexion of the wrist under anæsthesia undoubtedly gives satisfactory results with appropriate after-care. Where anæsthesia is to be avoided for constitutional reasons, the slower method is quite as satisfactory in its final result.

After the use of the conservative method with daily tightening of the strap on a long cock-up splint, rarely or ever does one see any loss of mobility in the arc traversed from flexion to hyperextension. The treatment should never be discontinued until fullest hyperextension of the wrist has been gained and held for some period. The time usually required is from four days to a fortnight. Massage and soaking of the hand in hot water, with immediate reapplication of the splint, undoubtedly accelerates progress. After full hyperextension of the wrist has been

A

B

C

D

FIG. 107, A–D.—Operation for inferior radio-ulnar joint ankylosis. This illustration shows the method devised for restoration of forearm rotation in cases of inferior radio-ulnar joint ankylosis. $\frac{1}{4}$ in. of the shaft of the ulna is removed close down to the ulnar head. Extreme care is taken to see that no periosteal shreds are allowed to remain. In addition we have hammered the ends of the bone after the technique of Sir Robert Jones to produce bone-scarring. The restoration of complete rotation is immediate and requires little or no after-treatment. In our series there has been no tendency toward recurrence of impaired rotation. The strength of the hand is almost unimpaired if the removal be made lower down than in this X-ray shown. A shows removal of section of $\frac{3}{16}$ in. of lower end of ulnar shaft for ankylosis of inferior radio-ulnar joint. The bone is better removed at the point indicated by the arrow than in the situation here shown.

gained, well-directed active exercises with resistance to flexion and extension are most useful. A short Jones cock-up splint should be employed during the course of treatment. It should only be discarded when the patient can actively flex and extend the joint with considerable power, and there is no further tendency to revert to flexion deformity. It is often useful to employ the splint at night only in the final stages of treatment.

INJURIES OF THE WRIST-JOINT AND CARPUS

Sprains of the Wrist-joint are commonly seen as the result of falls upon the hand, a sudden twist, or in the back-fire of a motor-car while cranking. While arising from a number of widely varying injuries, they may follow seemingly insignificant traumata. The diagnosis is being rigidly limited to those cases, mainly of ligamentous tear about the wrist-joint. The use of the X-ray serves to eliminate those cases formerly included, but really representing fractures of the various carpal bones.

Accompanying it may be seen a sprain of the thumb and traumatic synovitis of the neighbouring tendons on the dorsum of the wrist.

The swelling may be slight but in severe cases very marked from the outset, so as to make the exclusion of carpal fracture difficult. The bony relations of the styloid processes are of course unaltered. Tenderness is most marked over the particular lateral ligament ruptured and over the line of the wrist-joint. With the particular tenderness over the various carpal bones, where it may be impossible to definitely distinguish between fracture and teno-synovial reaction, the X-ray should always be employed.

The effusion in neighbouring tendon sheaths which so often accompanies wrist sprain may persist for several weeks and is frequently an important factor in the disability.

Treatment. All wrist sprains should be treated in the early stages with immobilization in the dorsiflexed position on a suitable cock-up splint (Fig. 108), in fact Sir Robert Jones has laid down the rule that every injury of the wrist below the level of a Colles fracture may be safely treated in this position. Should the injury be severe enough to end in ankylosis, the grasp of the hand is almost unimpaired. Disregard of this principle will cause prolonged disability from the wrist which has been allowed a flexion deformity. The fingers may be allowed freedom of movement from the very outset in pure wrist sprains.

Warm baths and massage in the subacute stages may be used, but, at the outset, rest of the joint should be the guiding principle. Active exercises, when they do not excite pain, are of definite value. A firmly fitting strap about the wrist or, in severe cases, a moulded leather wristlet which dorsiflexes the wrist is an excellent convalescent support.

Strains of the Wrist are most often seen as occupational disabilities. They follow lifting of heavy weights or from over-use of the hand. Bricklayers are said to be unusually susceptible to teno-synovitis of the left hand in the extensor ossis metacarpi pollicis and the extensor primi internodii pollicis tendons. Wrist strain is common in pianists, organists, and stenographers. It is most frequently felt after over-use of the hand following a long period of rest. The pain is acutely felt on the dorsum of the wrist and referred upward over the bellies of the extensor muscles of wrist and fingers.

Treatment. This condition yields to carefully graduated active exercises, which should be increased gradually until full function has been

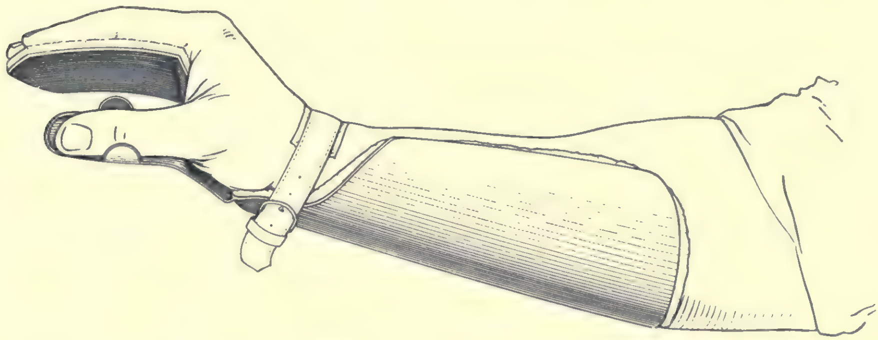


FIG. 108.—Jones's long cock-up splint with hand in functioning position.

obtained. A recurrence of pain is the safest indication that too much freedom is being allowed. Use of the joint within the limit of pain must hasten recovery, but, on the other hand, over-use in spite of pain usually serves to delay the complete return to normal.

INJURIES OF THE WRIST-JOINT AND HAND

Fractures of the Carpus. Fractures of the various carpal bones usually occur as the result of a fall upon the extended hand. Any of the bones may be the seat of the fracture, but the proximal row are most commonly affected and the scaphoid more frequently than any of the others.

Fracture of the Scaphoid is usually transverse and across its narrowest part. In mild injuries there may be no displacement but its characteristic signs are usually definite. Tenderness in the ' Anatomist's snuff-box ' and pain increased by dorsiflexion and radial flexion of the hand are usually seen. The swelling may be localized on the radial side of the wrist. The maximum tenderness of a basal fracture of the metacarpal of the thumb (Bennett's) can be distinguished from scaphoid fractures as being lower down. One-half of the scaphoid may be dislocated on the dorsum of the wrist.

Multiple carpal fractures are not uncommon. They may be compounded and complicated by dislocation of a whole bone or a fragment.

Treatment. In simple fractures without displacement and in all others, the wrist should be treated in the dorsiflexed position on a cock-up splint. Where a dislocated bone or fragment makes dorsiflexion of the wrist difficult, strong traction should be made on the hand while sharply flexing the wrist. Then pressure on the dorsally displaced fragment may cause it to slip back into position and allow the hand to be placed in dorsiflexion. Should this manœuvre be unsuccessful the fragment should be at once cut down upon and removed.

The prompt action of the surgeon in placing the wrist in its hyperextended functioning position after carpal fracture will undoubtedly avoid long periods of disability from painful and weakened grasp. The operative removal of dislocated fragments will surely have the same effect and will preserve mobility in certain wrists that would otherwise be stiffened by callus formation. The loss of the fragment is not disabling. The operative incision is best made on the dorsum by the paratendinous routes (Fig. 109).

Older cases with stiffened wrist in more or less of flexion deformity usually have considerable disability in power of grasp. These cases should be wrenched into hyperextension under anæsthesia and maintained upon a cock-up splint for at least a month. A night splint after this interval should be worn as long as there is any tendency to relapse into the old deformity. Exercises for the wrist extensor muscles will make the final result more certain.

DISLOCATIONS OF THE WRIST

Dislocation of the Inferior Radio-ulnar Joint is rare except as a complication of wrist fracture. It may occur as the result of forcible twist of the hand into pronation. The dislocation consists of a displacement of the ulnar head backward on the dorsum more commonly than forward or inward. The condition is easily recognized by the prominence of the whole ulnar head on the dorsum of the wrist, with almost constant pronation of the hand. Supination is particularly painful.

Treatment. Reduction usually is easy by manipulation. Pronation is first increased. Then, while making forward pressure on the ulnar head, the hand is at the same time sharply supinated. Slight flexion followed by extension of the wrist may be of additional help. The splint employed should maintain wrist hyperextension in the supinated position for several weeks.

Radio-carpal Dislocation is comparatively uncommon and most apt to be confused with the more common Colles's fracture. It is often

associated with fracture of the lower end of the radius or its styloid process, but in any event it is always accompanied by extensive tear of ligaments or other accompanying soft parts.

The carpus may be dislocated forward or backward, more frequently the latter. Backward dislocation of the carpus may be confused not only with Colles's fracture but with separation of the lower epiphysis of the radius. However, the dorsal projection of the carpus in dislocation is lower down than in either of the others. The relations of the styloid

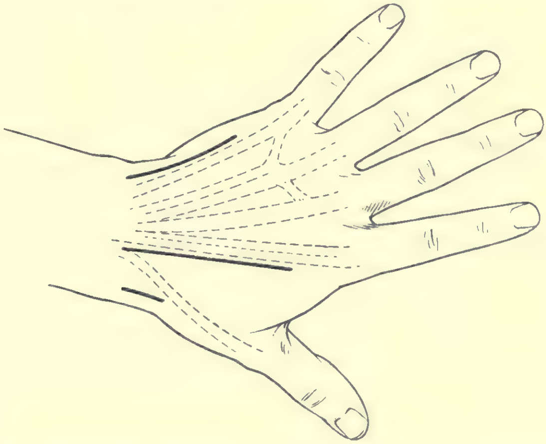


FIG. 109.—Ollier's paratendinous routes for incision in wrist-joint drainage.

processes are unchanged. The carpus is found to lie in a plane posterior to them. The palm is shortened and the hand more flexed than in injuries of the lower radius. The forearm is not shortened.

In dislocations palpation of the radius may reveal none of the joint tenderness seen in fractures, unless there should be periosteal bruising as well. The X-ray should be employed to differentiate such complications from fracture.

Forward dislocations, usually the result of falls or other traumata producing forced flexion of the wrist, are much less frequent. There is marked prominence on the ventral aspect of the wrist and a depression below the radius on the dorsum.

Treatment. Reduction is usually easy with traction on the hand and direct pressure of the carpus into position. In older cases preliminary manipulation to stretch shortened soft parts and break up adhesions will be necessary before the carpus can be levered back into normal relation with the lower end of the radius. Fixation of the wrist in slight dorsiflexion is desirable in cases of backward carpal dislocation. In the rarer form of anterior dislocation the mid position may be most satisfactory. Fresh cases may not require more than a week of complete

fixation before exercises are allowed. Neglected cases, in which reduction has not been done for several weeks or months, will require splinting for a much longer time.

DISLOCATION OF THE CARPAL BONES

Dislocation of the individual bones of the carpus is a rare occurrence. According to Thomson and Miles, the os magnum, the semilunar, and the scaphoid are the most frequently involved in the order named. Unless accurate reduction can be secured, much disability is saved by exsection of the whole bone or loose fragment.

INJURIES TO THE FINGERS

Carpo-metacarpal Dislocations when they occur usually present a characteristic and easily recognized deformity with the bases of the metacarpals displaced backward on the carpus. The thumb is most often affected. The diagnosis must eliminate Bennett's fracture of the base of the first metacarpal, to be described later.

Treatment. It is easier to obtain reduction than to hold it in position afterwards. A properly moulded metal splint on the dorsum of the hand, with a small felt pad directly over the metacarpal base, can be satisfactorily adjusted.

In basal thumb dislocations, great care should be taken to secure a position of complete abduction. A thin metal splint can be easily cut with heavy shears. The tendency to redislocation may make it necessary to employ full extension as well as abduction of the basal joint. This position should not be maintained longer than three weeks, unless actually necessary, because of the weakening effect upon the opponens and flexor brevis pollicis muscles and consequent impairment of function. The thumb should be moved forward into its functioning position (of opposition) just as soon as all tendency to redislocation has disappeared. Gentle movements and exercises may be given early, but if the all-important position of abduction is maintained, there is little to fear from disabling adhesions.

Recurrent dislocation of the thumb metacarpal should be treated operatively. It consists of an erasion of the joint (described on p. 277). The attempt should be made to secure a fibrous hinge by removing the cartilage of the thumb carpo-metacarpal joint. By the use of traction or early movements in the post-operative treatment, a bony ankylosis of the joint may be easily avoided. The thumb should be placed in its functioning position described above.

Fracture of the Metacarpals of any of the four fingers is quite common both from direct and indirect violence. The condition has always been

considered as a minor injury and has not been given the attention it deserves. The cases traceable to indirect violence usually show the oblique fracture. Those of direct violence, such as a blow, will often be transverse and have little, if any, displacement. Gunshot fractures in war injuries may not only have large losses of substance, but the usual displacement of fragments as well. Fractures of the base often heal without any disability. The fractures of the shaft and near the head may be very difficult to treat and produce most troublesome disability, dependent upon several factors.

There is an almost constant tendency to dorsal bowing of the fragments. As a result there is shortening of the affected bone and its head not only retracts but flexes into the palm. The ordinary prominence of the knuckle is lost. In cases ineffectually treated, leaving the deformity not wholly corrected, there is always imperfect flexion of the knuckle. Should the fracture occur in the third or fourth fingers the disability is much greater, and in the case of the fourth particularly, the flexion of the third and fifth fingers is nearly always impaired to some extent.

The limitation of the flexion is traceable to a combination of circumstances. The knuckle is recurvate with shortening occurring in the posterior part of the capsule. The mechanical advantage of the lumbrical muscle is impaired by the sinking of the metacarpal head into the palm. In this way the muscle becomes a very inefficient flexor of the metacarpo-phalangeal joint. The intercommunicating bands on the extensor tendons of the three inner fingers often exert inhibiting influence on the extensor tendon, thus limiting flexion of the neighbouring fingers. This action is seen even after amputations of the fourth finger, unless the bands are also cut at the operation.

Treatment. Fractures of the metacarpals with displacement should, in all cases, be treated with efficient finger traction at the very outset. When the fragments are in good alinement and there is backward bowing on the dorsum of the hand, the traction should be supplemented by a dorsal compression pad of felt at the site of fracture and a palmar pad which will push the metacarpal head back into its normal relation. This maintains the transverse palmar arch of the hand. Really efficient traction will keep the finger down to length. It must not be relaxed at any time until soft callus has been thrown out. Fractures of the fifth finger are not so disabling, but unless traction be employed the finger flexion may be so poor that the patient will later demand its amputation. The traction splint to be employed will vary. Splints shown in Figs. 110 to 115 or their modifications will prove efficient.

Bennett's Fracture, the old time 'Stave of the thumb', consists of a basal fracture of the first metacarpal into the joint. The fragment is usually oblique from the inner portion of the base toward the index

finger. It is often the result of a blow with the closed fist and, naturally, is not uncommon to pugilists.

It is best treated by traction with the thumb in the fully abducted position. The nature of the fracture and the great mechanical advantage of the adductors over abductors of the thumb make the disabling adduction deformity a common sequel, unless special effort is made to avoid it. With the use of traction stiffness of the basal joint can usually be prevented. In any case, should short fibrous adhesions supervene, there is very little disability if complete abduction of the thumb has been secured with a moderate amount of opposition—in fact, the position of the thumb when holding a glass of water is the best guide.

Fig. 115 shows a traction thumb apparatus easily made from plaster of Paris, heavy wire, and rubber tubing.

Jones's metal 'Shoehorn' splint is useful but does not permit of applying traction.

Dislocations of the Metacarpo-Phalangeal Joints are backward in most instances, with the base of the proximal phalanx prominently felt posteriorly. The thumb is more often affected than all the others, resulting from forced hyperextension. The head of the metacarpal is felt between the heads of the flexor brevis pollicis muscle. The whole picture of the deformity is quite characteristic. The dislocation may be partial or complete with overlapping of the bones following rupture of the anterior ligament.

Treatment. The great power of the flexor longus of the thumb and the other flexors in the case of the fingers make reduction by traction quite impossible. The hyperextension deformity should be greatly increased while the proximal end of the phalanx is pushed over the metacarpal head by leverage. The thumb is then flexed. Should torn ligament interpose to make accurate replacement impossible, open reduction should be done. A diminutive gutter-splint, applied dorsally, with pad over the proximal end of the phalanx is sufficient to maintain reduction. Flexion movement only should be allowed for a long period, in view of the marked tendency towards recurrence.

Fractures of the Phalanges are seen most frequently in the proximal row and occur from direct or indirect injuries. They are frequently compounded and often involve a joint. Their recognition is not difficult, but X-ray is usually advisable in that it gives valuable information for special splinting.

Treatment. Finger traction until now has been too infrequently used as an adjunct to the splinting. It is unnecessary in fracture without displacement, but where accurate position of the fragments has not been secured, it will procure excellent alinement. It offers the advantage of stretching the tendons and capsules of neighbouring joints, thus prevent-

ing disabilities in flexion and later use of the fingers. Accurate position of fragments with efficient immobilization reduces the callus formation to a minimum and renders the involvement of tendons in callus or scar much less likely. In the convalescent stages warm baths and massage are of definite value.

STIFFNESS IN THE JOINTS OF THE HAND AND FINGERS

Stiffness in the joints of the hand and fingers, following war wounds or industrial accidents, goes far to make the most important disabilities with which modern reconstructive surgeons have to deal. There is hardly an occupation wherein a disabled stiff hand does not interfere more with the patient's earning power and daily convenience than does the loss of a foot or a leg. In this section we shall not include those cases which have gone on to bony ankylosis after extensive loss of joint cartilage. Those cases will be discussed later. We wish particularly to consider the partly or completely stiffened hands whose fingers bend little, if any, and are useless for purposeful movements of grasp. They are frequently shiny, atrophic, and rigid, and are sometimes spoken of as the ' Congealed hand '.

One rarely, or never, sees a hand stiffened in a functioning position. This is due probably to the fact that the advantage enjoyed by one group of muscles over its opponents is usually far greater both in power and mechanical pull. Illustrative of this is the greater power in the wrist and finger flexors over their antagonists—the extensors—and the far greater mechanical advantage of thumb adductors over thumb abductors. As a result of this, a wrist, when untreated, usually stiffens in flexion and a thumb in adduction deformity. These deformities into which ineffectually treated hands lapse at the period when stiffening is going on are due to a multiplicity of causes. The war deformities of hands seen at orthopædic centres represent, therefore, not the true deformities of the particular fracture which may have occurred, but rather the composite deformity of the fracture, the severed adherent tendons, or the paralysed intrinsic muscles of the hand. To these and many other factors is added the possible deformity of position allowed the hand in the course of treatment until healing has occurred.

Probably the greatest number of stiff hands are traceable to prolonged immobilization following wounds anywhere in the upper extremity. High-up wounds give this result less commonly, but the frequency is directly increased the nearer the wound may be toward the hand or wrist. Difficulties of prophylaxis and treatment increase in the same direction.

In direct wounds of the hand itself, troublesome stiffness is present in an overwhelming number. This is due, no doubt, to the fact that

war and industrial wounds of the hand offer such great obstacles to early movement and massage, on account of the extreme likelihood of lighting up the infection to produce a general cellulitis.

Hand stiffness following the ligation of the brachial artery is a common and unusually troublesome condition. The great factor in causation must be the general fibrosis in the joint itself and the structures about it following upon the impairment of their blood supply. However, such arm wounds requiring brachial artery ligation, will often result in partial or complete lesions of the median or ulnar nerves as well. In such cases the hand and fingers will not tolerate prolonged immobilization on splints without very serious results.

Nerve lesions alone are often seen to produce most marked stiffening of hands. Particularly is this true in certain ulnar and median nerve lesions where the nerve supply of the interphalangeal joints is lost. In such cases, where joint sense is partially or completely lost, we have the warning that continuous immobilization of the fingers on splints will not be borne without danger of serious joint stiffening. The attendant danger of flexion contractures of the affected finger seems to be avoidable by the merely part-time use of extension splints, thus allowing daily periods of hand freedom for passive movements.

Hand and finger stiffness resulting from prolonged immobilization plus nerve injury, has a very much more serious prognosis as regards future function than do cases uncomplicated by nerve lesion. The stiffness itself, while infinitely more difficult to treat because of the stubborn tendency towards contracture even after long periods, is not the most serious factor. The paralysis of the important intrinsic muscles of the hand, particularly the interossei and lumbricals, carries a much graver prognosis. Nevertheless, paralysis of all the interossei, with third and fourth lumbricals through lesions of the ulnar nerve, may leave surprisingly little disability for ordinary function of the hand. Paralysis of the intrinsic muscles of the hand, enervated by the median nerve, has a decidedly more serious disability for reasons that require discussion later. The fact must be remembered, however, that these complications affect the prognosis of a stiff hand under treatment.

The stiff hand, which has been the seat of a cellulitis and has required multiple incisions that involve tendons in scar, is a common sight in civil surgery as well as in that of war. Where these tendons have been interrupted, a proper estimate of the damage done is often difficult to make as long as the neighbouring joints are rigid. It is an unsound procedure to attempt operations for suture or transplantation of tendons so long as the joints they govern are still fixed by adhesions. They are rarely successful and the joint condition makes early movement through any considerable range an utter impossibility.

TREATMENT OF STIFF JOINTS OF FINGERS AND HAND

As a preliminary then to most surgery in the hand, the immobilization of the small joints of the fingers is essential. The wrist-joint, when not ankylosed, may be readily mobilized in the manner described previously.

The less severe cases of finger stiffness will be readily relieved by prolonged warm baths with frequent immersion of the hand into cold water. This ' contrast ' bathing with its alternate vaso-dilation and vaso-constriction action on the smaller blood-vessels, undoubtedly improves the circulation and tone of the hand. Gentle bending of the fingers under warm water while traction is being made is very useful. Heavy massage, except where it is painful, may be carried out, but more important than this is active exercise of the fingers by the patient himself. At this period the value of curative workshops for such hands cannot be over-estimated.

At the outset it should be stated that the results of manipulation of very rigid fingers under anæsthesia has been, in our hands, very disappointing. We have come to believe that its successes were mainly among those cases of lesser severity where massage and hydrotherapy alone would have given the same result. In those severe cases, where ether manipulation starts up great reaction and the joints finally re-stiffen, there can be no question but that this treatment does harm.

Led by such circumstances the principle of traction for stiff fingers was tried at the Edinburgh War Hospital in 1917. At that time Captain Abbott devised a plaster splint combined with rubber elastic traction taken off of tapes from over the various finger-joints from a glove. These tapes pulled over metal bridges drawing the fingers into the palm. This marked a distinct advance in our treatment and certain cases which were not helped by massage or electricity given previously, were improved. There were, however, a certain number of cases which would re-stiffen in the flexed position. This led us to the conclusion that the mistake lay in not taking the pull directly off the ends of the fingers so as to produce actual separation of the joint surfaces, while stretching the adherent capsule and tendons around it. Further experiment brought us to the development of a splint (Fig. 110) which substitutes a steel spring for the rubber elastic. This allows direct pull to be taken off the end of the fingers by means of a strong cord attached to the adhesive. The cords pass to a series of four rachets on the end of the spring, allowing fine adjustment of the pull placed on each individual finger. The thumb is pulled separately to the spring shank in its normal functioning position (that of opposition). The substitution of the steel spring allows constant and even pull on the fingers in every stage down to complete flexion.

We have found that on the normal finger a pull of but four ounces

is sufficient to separate the surfaces of the metacarpo-phalangeal joints for a distance of 2–3 mm. Pull is easily obtained on this traction splint and in the course of a few days only, the stiffened and contracted tissues about the joints have been stretched so that the joint separation is easily seen by a depression in the skin over the knuckle. This may be verified by X-ray. At the outset the pull should always be taken in the line of the deformity. When separation of the joint surfaces has been secured the spring may be bent a few degrees at a time, until finally complete flexion of the metacarpo-phalangeal joints has been obtained, as seen in Fig. 111.

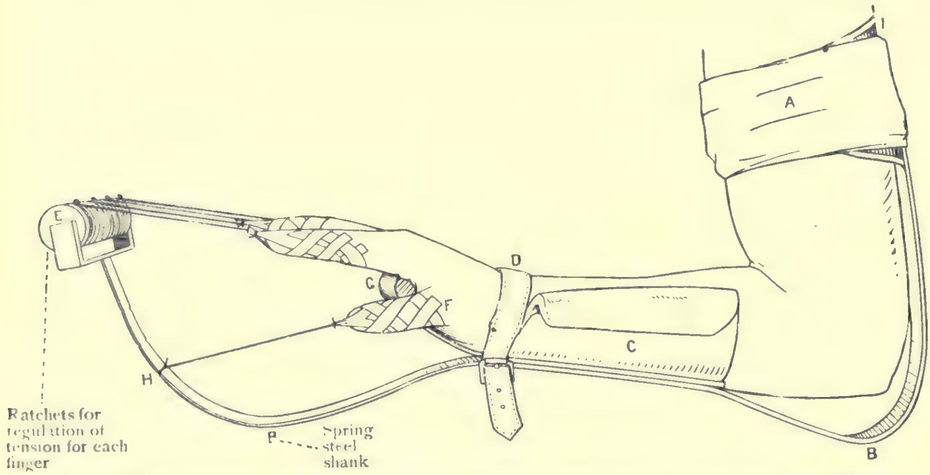


FIG. 110.—Author's finger traction splint. First position for traction of stiff fingers, until separation of joint surfaces is obtained.

This process should be proceeded with slowly. In easy cases never less than one week, and in more difficult ones never less than two, or even three months should be allowed for its completion. The splint should be worn constantly except for a few minutes for contrast baths, light massage, and active exercises. In general the active (voluntary) extension of the fingers should keep pace with the flexion. While the adhesive extension, as shown in Fig. 112, covers the interphalangeal joints, it will be found that they have been stretched and mobilized along with the knuckles which are always the more difficult to treat.

The principle of traction may be applied to stiff fingers by another method, used lately by Major Danforth. It consists of a bivalved plaster-of-Paris forearm and hand-splint, from the ventral surface of which a strong iron wire 'outrigger' supports the traction of rubber tubing (Figs. 113, 114). It has the advantage of being easy to make in any institution. Like the forearm traction finger-splint, it is easily detachable for massage.

Whatever the means chosen to apply it, we have found that in the

treatment of severe cases of stiff fingers the principle of traction to separate the joint surfaces is the very key-note. Without the separation of joint surfaces so easily obtained by traction, forcible flexion grinds the joint synoviæ together on the flexor side of the joint, thereby producing a traumatic synovitis that will wholly defeat our purpose. We are convinced that by this means many neglected hands, hitherto despaired of,

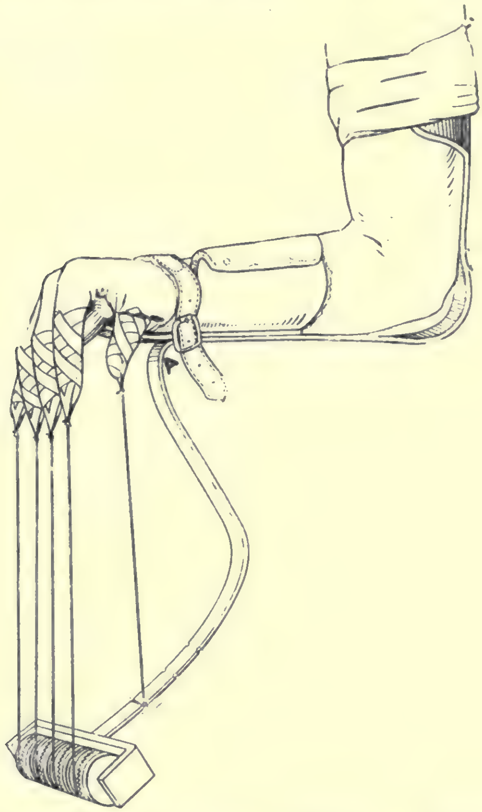


FIG. 111.—Final position of traction for stiff fingers, secured by bending the spring steel shank at the wrist.

can be reclaimed. Painstaking care is necessary whatever type of traction is employed, but the results are in direct proportion to the patience and interest the surgeon gives to the problem. Certainly no amount of time and effort should be deemed too great.

There can be but little doubt that contrast hot and cold bathing of these hands for ' circulatory gymnastics ' is of great value. Nothing, however, can wholly take the place of active ' voluntary ' exercises, first with assistance and then with resistance applied to strengthen the muscles. In the early stages of the treatment faradic stimulation of the

muscles may be a definite help, but there is little reason for its use after the return of voluntary power. One is often impressed by the fact that fingers mobilized by traction show almost no tendency towards recurrence of stiffness.

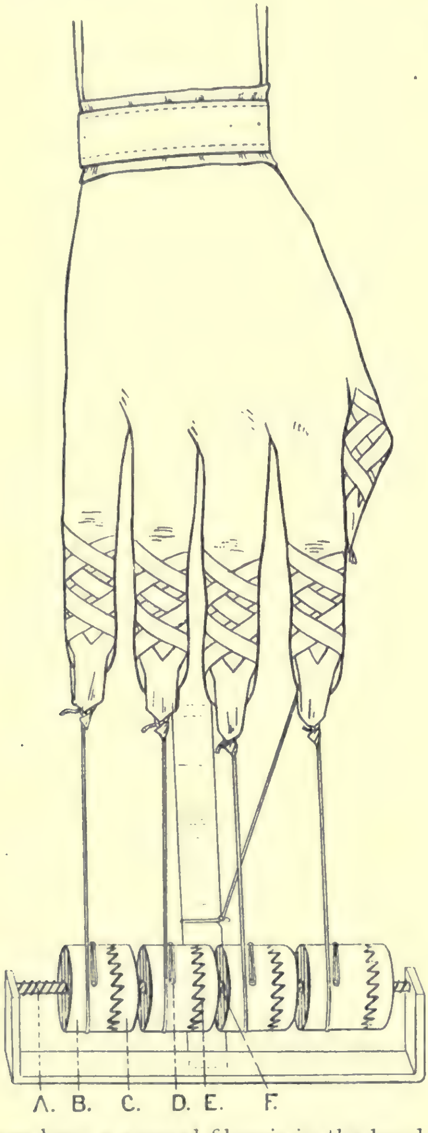


Fig. 112.—Detail of forearm traction finger splint.

A. Coiled spring to keep rachets in mesh.
B. Rotating portion of rachet.
C. Stable non-rotating portion of rachet.
D. Pin for attachment of traction cords to the rotating rachet.
E. Line of mesh of the rachet.

Note. The traction should be applied well up on the fingers as far as the web. The preliminary traction should be always in the line of the deformity until there has been enough stretch of the capsule and structures about the knuckles to produce actual separation of the joint surfaces. Following this the spring steel shank should be bent only at the point beneath the wrist where it joins the forearm piece. The curve of the shank itself should not be altered without having separation of the joint surfaces. The shank should be bent a few degrees at a time until right-angle flexion of the knuckles has been obtained. In the course of this flexion, which can be done gradually, the cords leading to the ratchets may be loosened every other day for voluntary exercises in extension. For the completion of the process in severe cases at least six weeks should be allowed, in some cases a bit longer. If the matter is proceeded with too quickly, reaction will be started in the joint; this is not necessary and we have found it harmful in that it delays complete recovery. If proceeded with carefully, stiff fingers mobilized by traction with this method will not relapse. The illustration here shows the fingers in the last position of flexion.

This method is particularly valuable in cases of ischemic paralysis where there has been a general fibrosis in the hand. It is a most satisfactory method for the treatment of nerve contractures of the fingers. The illustration shows complete correction of ulnar nerve contracture after thirteen days of traction. The patient is able to voluntarily completely extend his fourth and fifth fingers. They have remained flaccid since removal of the splint. We employ a night splint to maintain extension for a month following.

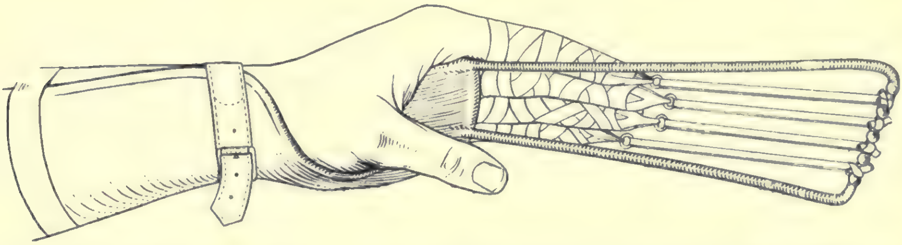


FIG. 113.—Danforth's plaster-of-Paris and wire splint for traction of stiffened fingers.

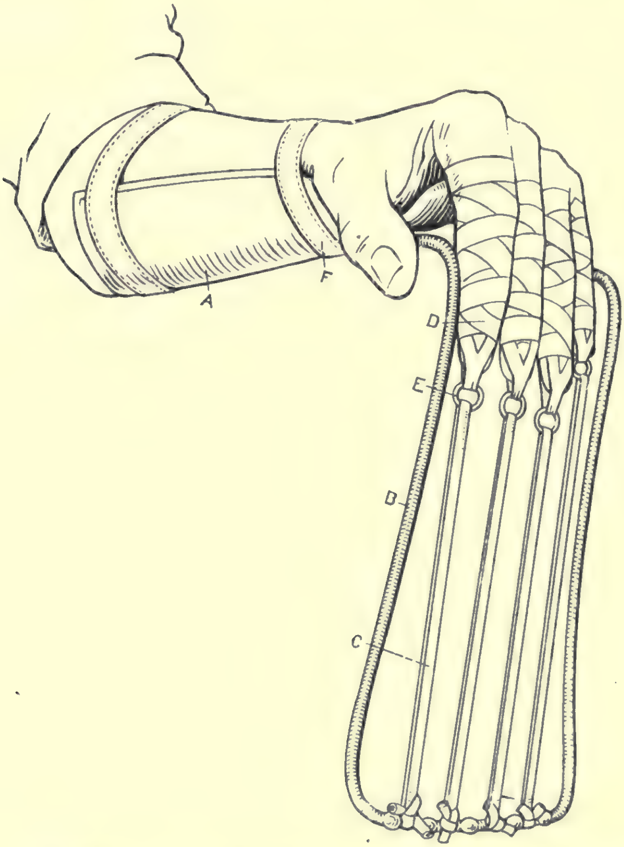


FIG. 114.—Last position of the same splint secured by bending wires. A. Moulded plaster-of-Paris 'cock-up' splint. B. Heavy iron wire 'outrigger'. C. Rubber tubing. D. Adhesive strapping for traction on finger. F. Retaining wrist and forearm bands.

FINGER CONTRACTURES

Flexion contractures of the fingers following nerve lesions or other industrial accidents are still far too common. After the healing of wounds or cuts upon the palmar surface of the hand or finger they make most troublesome sequelæ.

Treatment. Forcible correction of the deformity under anæsthesia and splinting has been abandoned in most centres for the more satisfactory method of gradually straightening the fingers on a metal splint. This method will undoubtedly give satisfactory results with patience and care.

We have come to favour the finger traction method as quicker and more complete in its cure. The finger traction splints (Figs. 110, 111, 112, 113, 114) are reversed in their order and from full flexion the finger is brought up to full extension by the steady elastic pull. We have seen severely contractured fingers made flaccid in three weeks by careful use of the traction method.

LATERAL DEVIATIONS OF THE HAND

Ulnar and radial deviations of the hand from lesions about the wrist are quite common deformities in war surgery. The latter is more severe in its disability for grasp of the hand. They arise from a multiplicity of causes.

Ulnar deviation is perhaps less common than radial and less severe in its effect upon hand function. Pure lesions of the ulna with even deficiencies of bone in the shaft do not produce deviation of the hand toward the ulnar side. Injuries to the ulnar shaft may, however, bring destruction of the muscular substance, the tendon, or the enervation to either the extensor or flexor carpi ulnaris muscles and cause a radial deviation of the hand. Injuries producing loss of bone substance on the ulnar side of the radial articular surface of the wrist-joint or on the same side of the proximal row of the carpal bones, often produce ulnar deviation. Perhaps one of the most common causes, however, is the weight of the unsplinted hand, carried in a sling during the course of a wrist arthritis. Injuries to tendons, or paralysis of the muscles on the radial side of the wrist, produce the most marked ulnar lateral deformities. The deviation is always accentuated by the pull of the unapposed flexor and extensor tendons on the ulnar side. Injury to the tendons or paralysis of the thumb extensors produces much more marked ulnar lateral hand displacements than does the loss of merely the flexor or extensor carpi radialis tendons alone.

Treatment of ulnar deviations of the hand must vary according to the underlying cause:

For sling deformities following non-support of the hand in the course

of arthritis of the wrist, prophylaxis, by use of a long cock-up splint, is sufficient. In cases seen late, where stiffness has occurred, manipulation under anæsthesia or replacement by open operation are indicated if the deviation be marked enough to interfere with hand function. In milder cases gentle manipulations following hot baths will be sufficient to overcome the deformity. A cock-up splint which prevents recurrence of deformity should be worn until the patient can strongly radially flex the wrist. To this end, re-education of the muscles which radially flex the wrist should be instituted early and continued with assisted and resisted active exercises. Where interruption of the thumb extensors is the cause, suture of the tendons or tendon transplantation will give the desired correction of deformity and return of function.

RADIAL DEVIATION OF THE HAND

Lateral deviation of the hand to the radial side may be due to loss of muscle or ligament on the ulnar side of the wrist or forearm. Fracture of the articular surface of the radius is a common cause. In war surgery at least a vast majority of the cases are traceable to fracture of the radius with subsequent overlapping or loss of substance. Any change in the radius which results in the loss of its normal outward bowing, must change the wrist-joint axis to give this lateral deformity. The most extreme of these deviations result from war wounds with actual deficiencies and non-union in the radius.

Severe radial deviation of the hand carries with it tremendous loss of function. The grip of the hand is extremely weak. There is usually a troublesome finger stiffness superadded. In cases of deficiency or gap in the radius, the hand deviation is due to several causes :

1. The shortening of the forearm, the length of which is always determined by the radius only.
2. The ulna being intact and the radius shortened, the lower radial fragment slips upward on the ulna—in severe cases for $\frac{3}{4}$ in.
3. The axis of the wrist-joint becomes oblique instead of horizontal, since the upper end of the lower radial fragment always approaches the ulna. Synostosis may supervene and complicate treatment.
4. Compound fractures of the radius usually show scar involvement of the soft parts on the radial side of the forearm. Their contracture makes the deformity still more marked.
5. Wounds and compound fractures of the ulna are often complicated by paralysis of the flexor or extensor carpi ulnaris muscles, or their normal contraction may be inhibited by scar tissue. Likewise the severance of their tendons may result in loss of wrist balance, and hence deviation of the hand.

Treatment. The various underlying causes of the deformity modify the treatment in each instance.

Mild adhesions in the wrist-joint following arthritis with subsequent positional deformity will yield most readily to warm baths and manipulation with or without anæsthesia. Suitable splinting should always be employed to maintain the hand in over-corrected position. Meanwhile, active exercises should be employed to strengthen the muscles governing ulnar flexion of the hand.

Where the deviation is dependent upon an isolated irreparable paralysis of the flexor or extensor carpi ulnaris muscles, the tendon of paralysed muscles may be sunk into the inner subcutaneous border of the lower end of the ulna. By this tenodesis the hand is held in the mid-position and radial flexion is inhibited. Flexion and extension of the wrist are not interfered with by this procedure. As in all operations

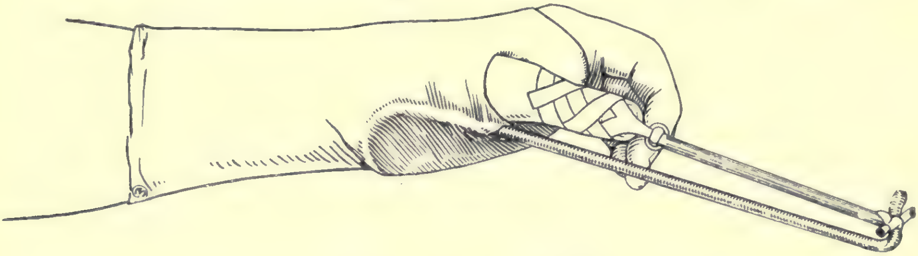


FIG. 115.—Plaster-of-Paris, wire, and rubber traction splint for fractures of the thumb.

which involve tenodesis (sinking paralysed tendon into bone), the over-correction of the deformity and stretching of the shortened soft parts opposing should be done as a preliminary to the operative procedure. Failures of such operations are often traceable to neglect of this principle.

Severe radial hand deviations, the result of deficiencies in the radius, must, of course, be attacked in the radius itself. Bone graft has been extensively used. In our experience this procedure has been disappointing in cases presenting marked derangement of the wrist-joint axis. Union of the bone may be secured, but where the lower fragment of the radius has slipped upward on the ulna, the hand deformity is almost never corrected by bone graft. Neither is the normal bowing of the radius restored. Pronation and supination are invariably limited in such cases, as a result of the encroachment of the ulna upon the dorsum of the carpus. The grip of the hand, after bone graft of the radius without restoration of the wrist-joint axis, only improves to a certain extent and still remains weak. The difficulties in the way of securing useful function, without considering the bad cosmetic result of bone graft, led us early in 1918 to attempt shortening of the ulna, thereby completely restoring the normal relations

of hand and wrist, and hence their function. By this procedure the radial bowing may also be restored. Another important factor is that the duration of disability is much less than that in the case of bone graft into the radial shaft even if that operation be most successful. We know in war surgery that this is not always the case and occasionally subsequent operations are necessary.

We have come to firmly advocate the two-stage operation, believing it will do much toward preventing unfortunate results which might bring into disrepute an operation which is fairly difficult in itself and which, for a perfect result, requires not only experience in bone surgery but most careful after-treatment from the surgeon attempting it.

As a preliminary we employ warm baths to the forearm and heavy massage to the scar to reveal, if possible, any remaining infection that may be present.

Primary Operation. The preliminary operation consists of excising the skin scar of the wound through which the radius will need to be attacked later. In the case where this scar does not seriously bind down tendons and does not involve the usual areas of approach to the radius, a new incision may be made. This is not usually the case, however.

After excising the scar the dense fibrous tissue about adjacent soft parts is most carefully removed. The track of scar tissue will then lead down to the radius where tough fibrous tissue usually presents in great abundance. This is excised until the bone ends are freed and a clean intervening bed of muscle only is left.

With lion-jawed forceps each of the two radial ends are seized in turn and manipulated until their movement is quite free and they show no further tendency to approach the ulna. In longstanding cases the upper fragment should be rotated inward (pronated) to break up adhesions about the radial head, because the upper radial fragment is always rotated outward by the pull of the biceps tendon. The hand and the lower fragment will usually be found stiffened in pronation and should be freely manipulated and finally put up in extreme supination.

Following the manipulation, the periosteum on each of the bone ends is incised longitudinally from the bone tip upward to beyond the area of bone sclerosis as shown by X-ray. The periosteum is then lifted and reflected upward by a very sharp rougine (periosteal elevator) so that flakes of bone are carried with it. The denuded bone is then trimmed away, preferably with sharp bone-cutting forceps, until freely bleeding bone is encountered. The wound is then closed in the ordinary manner and a forearm supinating splint applied.

The secondary operation is done as soon as the wound is soundly healed and the skin can again be properly prepared for operation. This usually requires two or three weeks. The uneventful healing of this

wound gives the surgeon every reason to suppose that subsequent operation in this area, when the ulna is to be shortened, does not carry undue risk of infection to the patient. A new X-ray should be taken.

The amount of bone to be removed may be easily estimated from the recent X-ray. If the interval between the bones is 1 in. and the carpal articular surface of the radius has slipped upward on the ulna $\frac{1}{4}$ in., the amount of bone to be removed from the ulna should be $1\frac{1}{2}$ in., allowing an extra $\frac{1}{4}$ in. for restoration of radial bowing and impaction of the two radial fragments.

The seat of election for the shortening of the ulna is partly determined by the situation of the gap in the radius. In general the two should not be opposite each other, as the position of the forearm is then too difficult to control. There is the added possibility of a synostosis occurring. Whenever possible the choice should be the lowermost part of the ulna, because of its greater ease of control. Furthermore, should non-union occur, its accompanying disability is slight. None of these complications have occurred in our series, however.

Secondary Operation. A curved incision is made over the inner subcutaneous border of the ulna and the flexor and extensor carpi ulnaris tendons retracted. The insertion of the pronator quadratus muscle need not be disturbed. Longitudinal incision of the periosteum is done and it is lifted most carefully from the whole circumference of the ulna over slightly more than the amount of bone to be exsected. The bone is then sawn through, preferably with a Gigli saw. The ends can then be displaced and 'stepped' for the depth previously estimated by X-ray (Fig. 116). This 'stepping' of the ulna may be done by Gigli saw and chisel, but is perhaps more accurately accomplished by motor saw. The latter method, in our opinion, is open to the criticism that the heat inevitably generated by the high-powered saw probably kills neighbouring bone cells. Probably this difficulty may be obviated by freshening the sawed surface with a sharp chisel or osteotome.

The radial incision of the preliminary operation is then opened and the two bones brought accurately together and the smaller tip impacted into the medulla of the larger end of the two fragments of the radius. The two previously reflected collars of periosteum are then sutured over the line of contact.

Meanwhile the 'stepped' ends of the ulna are firmly held in proper relation by sequestrum forceps. We prefer fixation by two bone pegs easily made from the exsected bone. These are pressed into the drilled holes by means of heavy forceps without hammering. This provides the exceptional instance where a square peg fits best in a round hole.

With the wrist and forearm held most carefully the wounds are closed in the ordinary manner. A plaster cast is applied immediately,

great care being taken not to displace the fragments. This seems best done by making two long plaster 'reinforcements' which are moulded to the front and back of the arm. Only when these have 'set' is the spiral covering bandage attempted. The forearm is in full supination and the hand in slight ulnar flexion. The cast, in every instance, extends from above the partly flexed elbow downward to cover the hand, excepting

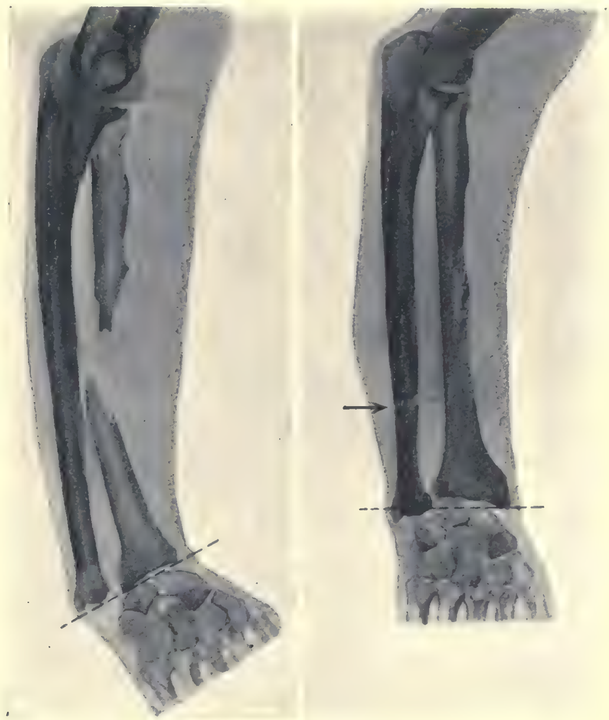


FIG. 116.—Before and after operation to shorten the ulna in cases of radial deficiency and non-union. Note the restoration of the normal axis of the wrist-joint. After removal of 1½ in. of the ulna at the point indicated by the arrow, power of grasp in the hand is normal.

the fingers. At the end of ten days the incisions are dressed through small windows cut through the plaster of Paris.

There has been no sepsis in any of our cases so treated, nor has there been non-union or other complications. Two cases, however, have required refreshening of the radius. The plaster cast may be renewed at the end of a month, using the utmost care as union will not yet have firmly taken place.

The largest amount of ulna we have had occasion to remove is 2¼ in. The muscles of the forearm will easily contract that amount by the time

union of the bone has occurred. The patient will then be able to completely flex or extend his fingers, which he is unable to do immediately following the operation. A strong freely-rotating forearm should result unless there are complicating injuries to inferior or superior radio-ulnar joints. The shortening of the forearm is in itself not at all disabling.

Where the radial deviation is due to fracture of the articular surface of the radius or carpus and the deformity is obviously the result of a displaced fragment, the latter should be removed by one of the dorsal paratendinous incisions of Ollier shown in Fig. 109. The technique is simple.

LATE OPERATIONS UPON TENDONS IN THE HAND

Industrial accidents, infections, and war wounds leave many problems for reconstructive surgery about the various tendons.

There is a very distinct class of cases where cellulitis of the hand has made multiple incisions necessary to control the infection. After these have been soundly healed the near-by tendons are frequently adherent in their sheaths. Where there has been no loss of substance in the tendon much can be done by flexion of the knuckles under traction. Combining it with contrast hot and cold baths, massage and exercises, the adherent tendons can often be mobilized satisfactorily without operative interference.

This treatment, however, will be quite ineffective against the heavy adhesions and the scar tissue of wounds. Such cases, just as in those where the tendon is severed, require open operation.

The tendon must be freed and sutured or not, as the case may be. Re-adherence is particularly liable to occur on the back of the hand where the metacarpals are subcutaneous. The early institution of massage just as soon as the skin is healed will prevent adhesions to the skin itself, but the greater difficulty comes from adhesions deeper in. We have used thin fat and fascia grafts from the inside of the thigh with success. The fat is turned upward (Fig. 117) allowing the tendons to rest in the bed.

Movements of the fingers are started in six to seven days, and, although the fat suddenly disappears about the sixth or seventh week, sufficient time has elapsed in which to gain a thoroughly mobile, non-adherent tendon.

Where direct suture of the ends of the tendon has been possible, we do not wrap the fat and fascia completely around it.

Where deficiencies exist in the tendon we have bridged the gap and wrapped fat and fascia about intervening strands of silk after the method of Kanavel. Transplantation of live tendon into the gap from the extensor brevis digitorum of the foot may be done.

OPERATIONS FOR CLAW HAND

In certain of the claw-hand deformities resulting from lesions of the median and ulnar nerves in the forearm low down, suture of the nerves may not be possible or return of power in the intrinsic small muscles of the hand may not be gained. Even where the flexors sublimis and profundus of all the fingers are active, the hand is useless for purposes of grasp.

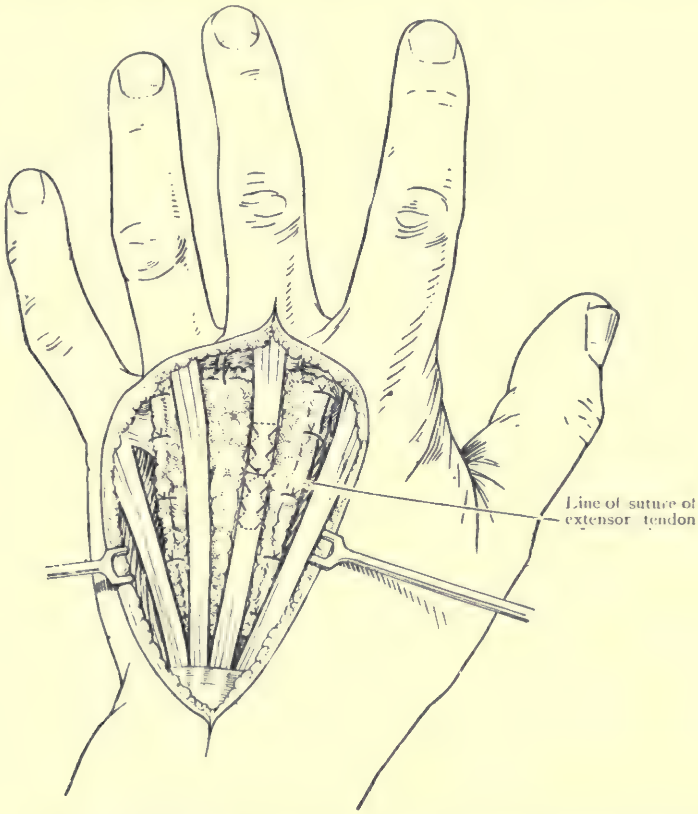


FIG. 117.—Fat and fascial graft from thigh beneath severed and adherent tendons on dorsum of the hand. Kanavel stitch for tendon suture allows immediate movement of tendon.

The mechanics of the disability is most interesting. The index finger slips by the thumb instead of meeting it tip to tip (Fig. 118, A). This is explained by the fact that the action of the flexor profundus to the index has lost its normal opponent, the lumbrical to the index, and it is not steadied by its opposing action through the extensor communis tendon.

The recurvate knuckle results from the paralysis of the lumbrical

which normally performs the bulk of the work of flexing the metacarpo-phalangeal joints. These two factors offer the main obstacle to efforts of grasp in claw hand. The following operation for 'slinging' of the

A B

FIG. 118.—A shows claw-hand deformity resulting from lumbrical and interosseus paralysis. Note the 'curling' of the index finger which makes opposition of thumb and index finger impossible. Lumbrical and interosseus muscles normally act as opponents of the flexor profundus tendons to prevent this deformity and to make accurate opposition of fingers possible as in B. (After Stiles's operation.)

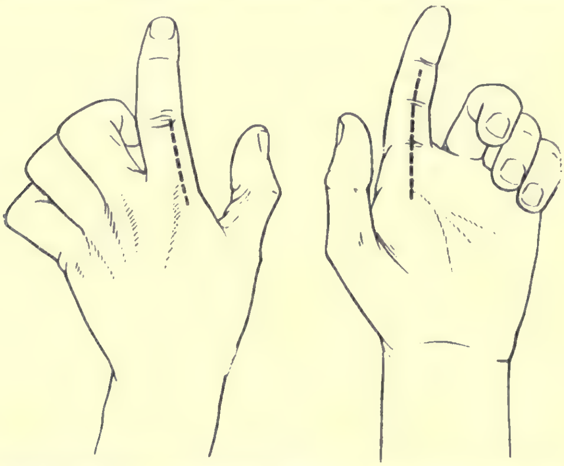


FIG. 119.—Showing palmar and dorsal incision for tendon slinging in paralyses of lumbricals and interossei. (Stiles's operation.)

flexor profundus tendons to compensate for lumbrical paralysis has been devised by Sir Harold Stiles.

Stiles's Operation. A mid-line incision is made on the palmar surface of the finger about 2¼ in. long (Fig. 119). The fascial envelope of the

finger is incised and the profundus tendon is exposed. The radial third of the profundus tendon is cut transversely at the level of the proximal interphalangeal joint and split up longitudinally toward the palm to just above the level of the metacarpo-phalangeal joint (Fig. 120). A second incision is made longitudinally just outside the tendon of the extensor communis over the proximal phalanx dorsally. A tunnel is made from this incision on the radial side of the phalanx through to the palmar incision, along the course of the paralysed lumbrical tendon. The cut portion of the profundus tendon is then brought through the tunnel from the palmar incision to the dorsal field of operation. With the finger flexed in the position of contact with the thumb, the split tendon is then fixed by three linen sutures to the freshened tendon of the lumbrical and to the point of its insertion into the tendon of the extensor communis. The suture should be made with just enough tension on the tendons to maintain the finger in the natural attitude of contact (between the palmar surfaces) of the thumb and the finger.

The incisions are closed in the ordinary manner and the finger dressed in a small plaster-of-Paris dressing to maintain the attitude of the finger described above.

The splint may be removed in two weeks for dressing and re-applied daily for several weeks after massage and warm baths. This treatment is followed until the tendon is strong. It will be found that the transplanted flexor profundus tendon will act as a flexor of the finger at the metacarpo-phalangeal joint and at the same time prevent curling up of the terminal phalanx (Fig. 118, B).

With complete paralysis of all the lumbricals and interossei, there is usually paralysis of the short thumb muscles as well. This paralysis results in flattening of the thumb with adduction and extension deformity. To remedy this condition the author has done an arthrodesis at the basal thumb-joint to procure a short fibrous union in the functioning position.

OPERATION FOR FLAT ADDUCTED THUMB DEFORMITY

A short longitudinal incision is made along the dotted line shown in Figs. 121, 122. The joint is laid bare and the thumb is twisted into fullest internal rotation, complete abduction, and slight flexion, e. g. the normal position of grasp for thumb and forefinger.

With a small osteotome the articular cartilage is then cut from the os multanugulum maius (trapezium) and the base of the first metacarpal. The incision is then closed and the thumb is encased in plaster of Paris, in the functioning position, for three weeks. Bony union is not liable to occur and the fibrous union will allow just enough flexion for useful movement. Fullest abduction and internal rotation of the thumb are

absolutely essential. A removable plaster splint should be continued until all tendency to return of mal-position has disappeared.

In our series the results of this operation have been excellent. Figs. 121, 122, showing the Stiles operation upon the index finger, also illustrates the author's operation upon the basal thumb-joint (Dr. Forrester-Brown's case).

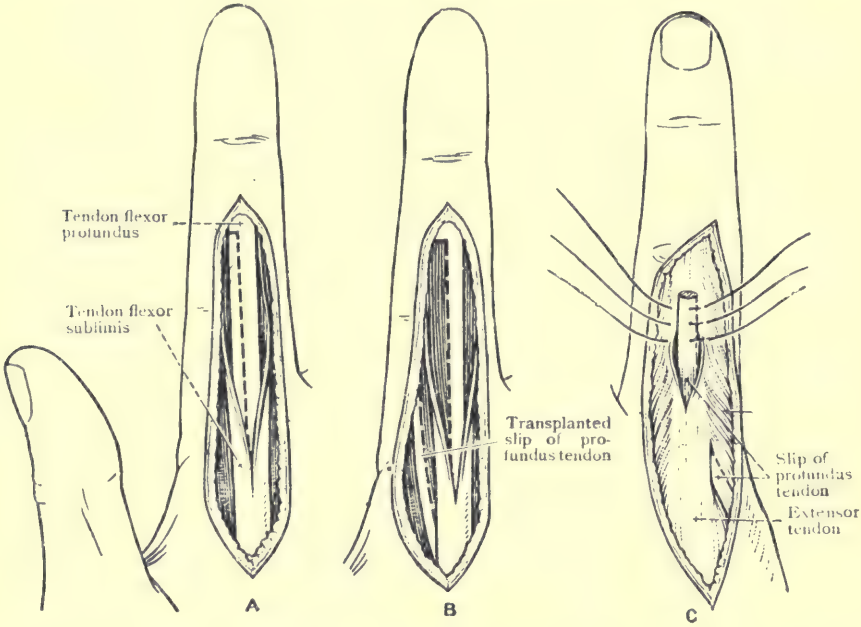


FIG. 120.—Stiles's operation. A. Splitting of the flexor profundus tendon beyond the division of the tendon of flexor sublimis. B. Displacement of the cut slip of the flexor profundus tendon subcutaneously to the dorsum of the finger for insertion into the extensor communis tendon. C. Sutures in position.

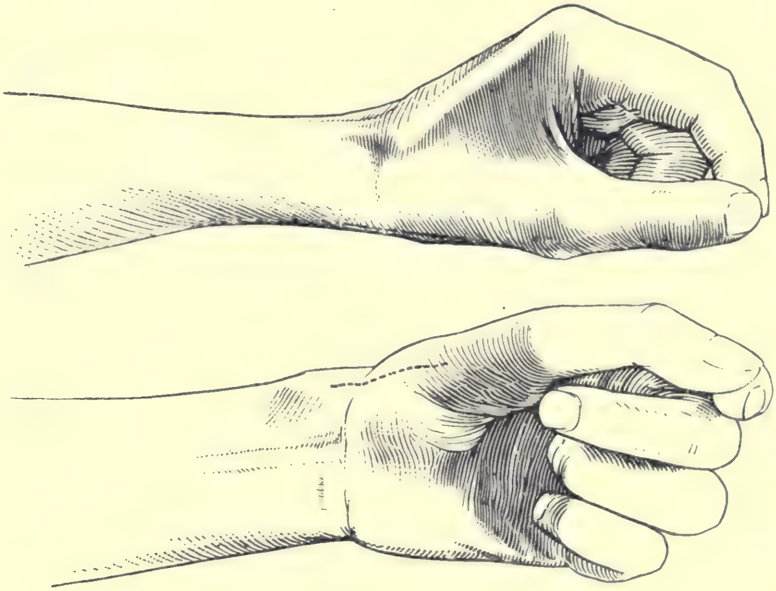
VON VOLKMANN'S ISCHMÆMIC PARALYSIS

Ischæmic paralysis of the hand was first described by von Volkmann of Halle in 1875 and 1881. It is associated with at least a partial interruption of the blood supply of the hand and forearm.

The cases seen in civil life usually follow fracture or severe injury in the neighbourhood of the elbow-joint. Many of them give a history of tight splinting or of uneven application of too firm a bandage. Thus by pressure from without there is at least partial inhibition of arterial supply and a retardation of the venous return from the structures below the injured area. On the other hand Sir Robert Jones states that pressure from within, resulting from hæmatomata and bruising of muscles by sharp bone fragments, is equally liable to be the causative factor. Main-

taining acute flexion of the elbow in the presence of marked swelling or œdema increases the danger of this complication.

In war reconstruction hospitals these cases are of common occurrence, resulting from wounds, not only of the forearm but the whole upper extremity. In many such cases the brachial artery has been tied and collateral circulation has been interfered with by swollen and ædematous muscles. Some are complicated by injury to the median and the ulnar nerves in the wound itself, or by scar during the healing.



FIGS. 121, 122.—Line of incision and final position of thumb after operation for flat adducted thumb deformity in paralyses of all the short thumb muscles. Note rotation of thumb and accurate opposition with index.

At the outset the muscles of the forearm may be swollen and firm, but with organization of the scar they become atrophic, shortened, and hard. The process may be more marked in one group than in another, but usually both flexor and extensor groups of muscles are taken. The fact that the later contractures are more marked in the flexors of the fingers and wrist is wholly due to the greater mechanical advantage of these muscles over their opponents. The hand presents the typically clawed deformity. The knuckles are hyperextended, the interphalangeal joints are fixed, and the thumb is usually held in adduction deformity. There are varying degrees of wrist flexion and pronation according to the severity of the case. The hand becomes ' congealed ' with its finger-joints varying from partial stiffness to complete rigidity. In mild cases there may be

no shortening of the finger-joint capsules, but in severe cases this may be most marked. The skin is often shiny, atrophic, and colder than normal. The finger nails are furrowed and rough. The radial pulse is often decreased in volume or absent.

Radiograms in older cases of severe type show atrophy of bone and pencilling of joint margins. The decrease of normal spacing between the phalanges indicates atrophy of cartilage as well.

The question of the pathology underlying the condition has led to a wide difference of opinion, but perhaps the largest number favours that of a coagulation necrosis primarily in the forearm muscles. Perhaps a better term would be a ' pan-fibrosis ' of all the structures of the hand and forearm, for no structure in the affected area wholly escapes the process. We have been impressed by the appearance of the ulnar and median nerves in such conditions. In the later stages they are invariably smaller than normal, and as a result of the coagulation charges are unusually hard. The near-by muscles appear pale and stringy.

The paralysis is rarely complete and no accurate idea of its extent can be gained until the joints have been mobilized.

Treatment. The treatment of Volkmann's ischæmic paralysis is not operative. The fact that complete flexion of the wrist will, in mild cases, allow straightening of the fingers, has led to operations for lengthening of all the tendons on the flexor surface of the wrist. Shortening of the forearm by excision of portions of both radius and ulna has been done. In our opinion this operation is neither justifiable nor necessary. There are instances, however, in the late stages of treatment, when the nerve changes in the ulnar and the median dominate the picture. In such cases it is advisable to free the nerves carefully and make longitudinal incisions in their sheaths. By this means we relieve constricting pressure about their nerve fibres. We have seen marked improvement in the intrinsic hand muscles follow this operation.

In war injuries where the ischæmic paralysis is complicated by a nerve wound, suture or freeing of the nerve should be done at the site of the lesion. With complete paralysis of isolated muscles, tendon transplantations are often necessary.

In the ordinary cases of civil life, however, the results of tendon lengthenings have been unsatisfactory because their shortening is only one factor in a generalized process.

Great improvement in the treatment was made by the method of gradual correction by the use of metal splints advocated by Sir Robert Jones. By flexing the wrist each finger can be bandaged separately to a splint in full extension. By bending the splint the wrist can then be gradually extended. In careful hands this method gives excellent results, but in the severer types is most difficult.

We have used the method (advocated also by Taylor) of constant steady traction for the shortened tendons of fingers and wrist. Fibrous tissue and scars will invariably stretch by this method which has the advantage of being so gradual that hæmorrhage and reaction do not result. All the structures shortened on the flexor surface of the wrist and the fingers share in the traction, and the adhesions in their tendon sheaths gradually give way leaving the tendons mobile.

By use of this method we have repeatedly seen disabled, shiny, and atrophic hands restored to function. The choice of traction methods

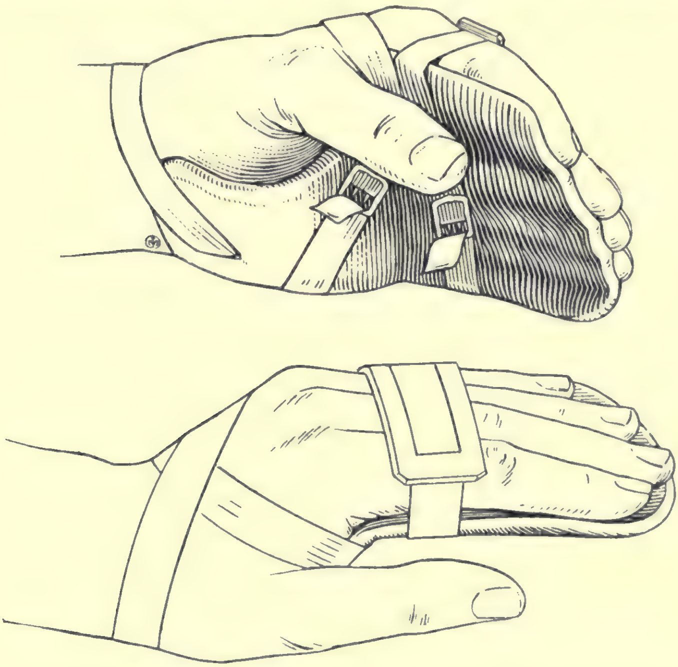


Fig. 123.—Danforth's palmar splint (papier mache) for paralyses of interossei and lumbricals.

(Figs. 110, 112) will depend on individual preference, but the traction method will produce a result in direct proportion to the patience and ingenuity of the surgeon employing it.

DUPUYTREN'S CONTRACTURE OF PALMAR FASCIA

Contracture of the palmar fascia resulting in permanent flexion of fingers was first described by Dupuytren in 1839.

Though occurring more frequently in men of middle age with a history of occupational traumata to the palmar fascia and its finger prolongations, it is also seen in many cases where no such history is obtainable.

Heredity, gout, and central nervous influences are ascribed by some authors as playing a part, but in a majority of the cases it seems traceable to the use of the palm in daily work, e.g. carpenters, gardeners, &c.

The pathology shown by dissections is primarily contracture and hypertrophy of the palmar fascia and its finger prolongations, and finally of the overlying skin. The hyperplasia of the fascial bands is sometimes uniform or it may be marked by fibrous nodules.

The fourth and fifth fingers are most affected in the flexion deformity.

Usually the onset is merely marked by a feeling of tightness in the palm, and then there is failure of extension in the proximal interphalangeal joint. While slow in its progress it seldom is arrested spontaneously, and proceeds to more or less complete flexion of the finger. Though the maximum of the flexion deformity is seen at the proximal interphalangeal joint the metacarpo-phalangeal becomes finally flexed. The distal phalangeal joint is not affected.

Treatment. The mild deformities in the early years of the contracture give so little inconvenience that no treatment is required.

In the more marked stages where the flexed finger presents an obstacle in the way of hand grasp, measures for its relief are necessary.

Conservative treatment is slow, painful, and often unavailing.

In our experience Dupuytren's open operative excision of the fascial bands has been disappointing in its results. The operation is often followed by the production of even greater amounts of scar tissue.

The subcutaneous method with multiple incisions as advocated by Adams is a very satisfactory proceeding, provided the post-operative care of the hand is carefully ordered. Immediately following the small radiating incisions, the finger is splinted in fullest extension. A week later the finger should be placed on elastic extension for two or three weeks. The unfailing use of a finger splint at night should be continued for several months and re-applied at any suggestion of the return of flexion deformity.

I wish to acknowledge my indebtedness to my Chief at the Edinburgh War Hospital, Colonel Sir Harold Stiles, A.M.S., for his inspiration, kindly help, and generous allotment of the cases which form the basis of this paper.

My best thanks are due to Dr. Forrester-Brown for her splendid co-operation.

DISTURBANCES OF THE LUMBAR SPINE AND PELVIC GIRDLE

BY

F. C. KIDNER

DISTURBANCES OF THE LUMBAR SPINE AND PELVIC GIRDLE

' LUMBAGO ', ' sciatica ', ' rheumatism of the back ', and similar terms are used to describe sets of symptoms which, in the great majority of cases, proceed from damage of some sort to the structures of the lower part of the back. Such damage is the result of acute injury, of chronic strain, or of disease, and most frequently affects the joints—the sacro-iliac, the lumbo-sacral, or the intervertebral. In order to diagnose correctly and treat intelligently these painful backs, it is necessary to bear in mind certain facts about the structure, mechanism, and abnormal anatomy of the region.

Structure. This consists of the two innominate bones, the sacrum, and the lumbar vertebræ which are connected by joints, the sacro-iliac, the lateral lumbo-sacral, and the lateral intervertebral, which have all the attributes of joints elsewhere—cartilage, ligaments, and supporting muscles. Their motion is slight but very real and of the sliding type. All of them have flat surfaces and are therefore unstable to lateral forces. All the joints are closely related and interdependent, so that a disturbance in one affects its neighbours. Under normal conditions the muscles and ligaments are sufficiently strong to maintain balance and to prevent excessive motion. Relaxation of the muscles and ligaments due to over-strain or to exhaustion may allow excessive motion or even displacement.

Mechanism. The sacrum is slung between the two innominate bones and supports the weight of the trunk through the column of the lumbar vertebræ. Unfortunately, the line of weight bearing is not a vertical one but, as a relic of our four-footed days, is tilted forward at a considerable angle. This fact results in a constant tendency, when the body is erect, for the sacrum and lumbar spine to slide still farther forward. This tendency is partially corrected by the gradual backward curve of the upper lumbar and dorsal vertebræ. In the main, however, it is controlled by muscular and ligamentous action. For this reason, the mechanism of the lower back lacks stability, and is out of balance. It is therefore inherently weak.

Abnormal Anatomy. The sacrum and lower two lumbar vertebræ are peculiarly prone to congenital variations in shape and form. These variations are developmental in origin, and most of them are the result of incomplete differentiation of the lumbar and sacral types of vertebræ.

A fifth lumbar vertebra may partake of one or more of the characteristics of the normal first sacral. It may have a very large transverse process on one or both sides, which may impinge upon or actually articulate with the top of the sacrum or the crest of the ilium. On the other hand, the first sacral vertebra may resemble on one or both sides the usual fifth lumbar and have small lateral masses. The lateral lumbo-sacral joints, which normally have a nearly vertical axis, may become almost horizontal. The various changes in the shape of the bones effect changes in the size, shape, or the direction of the different joints, which means lessened stability or loss of balance. Although such deformities frequently occur in individuals who never have any trouble with their backs, still they are potential sources of weakness.

With these preliminary remarks, let us proceed to the discussion of some of the actual lesions.

ACUTE STRAINS

1. **Simple Muscular Strain.** There is a class of patients who, after heavy labour or lifting, develop soreness and stiffness of the lower lumbar region, which causes partial disablement for a few days and gradually wears off without any special treatment. These cases are simple muscle strain and deserve no special attention.

2. **Acute Strain or Sprain of the Sacro-iliac Joints.** This may follow any form of traumatism to the lower part of the back, whether the result of heavy lifting, of carrying heavy weights, or of a fall or blow. The patient realizes at the time the injury is received that he has hurt his back. There is a sharp pain in the lower lumbar region : difficulty in holding the body erect, and, very often, a sensation as though something had snapped. Usually in the milder cases the pain disappears in a few minutes, and then after rest will reappear, becoming more and more severe during the succeeding twenty-four hours, until the patient is completely disabled. The pain is at first sharply localized in the region of the damaged joint, but gradually spreads through the whole lumbar region. Physical examination shows a marked spasm of the erector spinæ, especially on the side affected. This is often so great as to cause a deviation of the trunk towards the affected side. Tenderness over the joint itself can usually be elicited on deep pressure. Occasionally distinct fullness of the sacro-iliac joint itself can be felt. This is due to a collection of fluid within the joint. With the patient on the back, flexion of the thigh of the affected side with the knee straight is markedly limited (Kernig's sign). This is due to the pain caused in the joint by the pull on the ham-strings. If the patient is able to stand it will be found that lateral bending of the trunk away from the affected side is much limited.

This is due to the spasm set up by the irritation caused by the pull on the joint.

Sometimes a traumatism of the sacro-iliac joint is so severe or applied in such a way as actually to cause a partial dislocation. This is particularly likely to happen in a joint which is abnormally formed because of one of the variations in the development of the first sacral segment. In such cases the symptoms and signs are those described above for the ordinary sprain, except that they are more severe. In the marked case the displacement can be felt. It consists of a slipping forward of the upper part of the sacrum on the ilium, and is rarely greater than a quarter to a third of an inch.

X-ray examination is of comparatively little value in the cases of sacro-iliac sprain because the separation occurring at the joint is so slight that it is not recognizable. In partial dislocations a good stereoscopic X-ray may show the displacement quite clearly.

The treatment of the acute sprain of the sacro-iliac joint must be founded on complete rest. There is true synovitis and while this exists complete rest is as necessary as it is in synovitis of the knee or ankle. It can be best obtained by putting the patient on a bed, so arranged that the mattress cannot sag, and by placing underneath the lumbar spine a firm pad which supports the normal lumbar lordosis. In this manner strain is removed from the damaged joint. Prompt relief from pain is the sign that the rest is efficient. Firm adhesive plaster strapping so applied as to draw the two ilia together and thus anchor the sacrum aids in providing complete rest. If these simple measures are not sufficient to relieve pain, then it is sometimes necessary to place the patient in a plaster-of-Paris jacket, or plaster-of-Paris spica.

In the cases in which partial dislocation has occurred the first aim of treatment must be to reduce the displacement. Ordinarily complete rest as described above will so relieve spasm and pain that the joint will slip back into position of its own accord in the course of two or three days. If this does not happen, it is necessary to manipulate the joint, as must be done in any other dislocation. This manipulation should always be done under a general anæsthetic. No one series of motions will be successful in all cases, but the basis of the manipulation is the use of the thigh and ham-strings as levers to pull the backward displaced ilium forward on the sacrum. Success in manipulation will almost invariably be heralded by a sharp click, as the joint goes back into position. After reduction of the dislocated joint, the treatment is the same as that of the simple sprain. In the treatment of either condition complete rest is the first essential, and must be continued until pain in motion has entirely disappeared. Not till then should the patient be allowed out of bed. If he is allowed up too early, recurrence of symptoms is sure to occur.

If, on the other hand, complete rest is sufficiently prolonged, convalescence will be uninterrupted. Usually ten days in bed will accomplish the result.

3. **Acute Strain or Sprain of the Lateral Lumbo-sacral Joints.** The causes of this condition are the same as those of the sacro-iliac joints with the addition that there is more apt to be an element of twisting in the causative trauma, e.g. cranking of a heavy automobile engine. The onset of the symptoms is similar to that of the sacro-iliac injuries, except that the pain is placed somewhat higher and is more deeply seated. On physical examination, the following signs will be found. There is marked spasm on both sides of the erector spinæ muscles. Deviation of the trunk toward the affected side is more marked than in the sacro-iliac cases. There is a marked increase of lumbar lordosis : tenderness is difficult to elicit because of the deep-seated position of the affected joint, but can be made out. Limitation of voluntary motions of the lower part of the spine is more marked than it is in the sacro-iliac cases. Because of the close proximity of these joints to the nerve roots as they emerge from the spinal canal there is frequently an accompanying sciatica. With the patient lying on the back, it will be found that the thighs can be flexed through the normal arcs with the knees straight. This is in direct contrast to the sacro-iliac cases, and depends on the fact that the pull of the muscles of the ham-string on the innominate bone is not transmitted to the lumbo-sacral joint.

Partial dislocation of the lumbo-sacral joint also occurs. Symptoms and signs are those of sprain, but as in the case of the sacro-iliac are more severe.

X-ray examination of the injuries to the lumbo-sacral joint is more valuable than in sacro-iliac cases because slight changes are more easily recognized.

The treatment of the sprains is complete rest carried out as in the treatment of the sacro-iliacs. It must be, however, more prolonged and of a more rigid character if recurrence is to be avoided. The manipulative reduction of the partial dislocation of the lumbo-sacral joints is difficult, and should be undertaken with the greatest care because of the danger of complete dislocation during the manipulative procedures.

Fracture of one or both articular facets, which go to make up the lumbo-sacral joints, is not uncommon, and is the cause of many severe cases of prolonged backache and sciatica. It can be differentiated from sprain or partial dislocation by careful X-ray examination. It must be treated by prolonged fixation in some form of rigid jacket. Such fixation is necessary to limit the amount of callus formation. If much callus forms pressure on the adjacent nerve root is inevitable; such pressure will always cause pain and may cause paresis.

Occasionally sprains or partial dislocations or even fractures of the lateral intervertebral joints in the upper segments of the lumbar spine occur, but they are less common than at the lumbo-sacral level.

In all acute lesions of the lower spine rest is absolutely essential, as it is in acute injuries of joints elsewhere in the body. Massage, electricity, passive or active motions during the acute stages are positively harmful in that they keep up the irritation of the damaged joint. Heat, on the other hand, applied in any form such as hot compresses, hot-water bags, or electric baking, is of distinct value in relieving the pain and discomfort.

When acute symptoms have subsided and pain has completely disappeared the return to normal activity should be carried out with great care. Strict supervision of the patient should be insisted upon and increasing exercise allowed only in the absence of pain. Return of pain demands immediate reduction of activity. If these precautions are not observed, the tendency to recurrence and to the ultimate establishment of a more or less chronic disability is very probable. In the later stages of convalescence massage and graduated exercises are of use to restore tone to the weakened muscles and ligaments.

The acute strains and sprains, common enough under normal anatomical conditions, are much more common when any of the abnormalities of development in the bones are present. A long transverse process of the fifth lumbar vertebra, which impinges on the crest of the ilium, may in certain positions of the body act as a very powerful lever to throw extraordinary strain on either the sacro-iliac or lumbo-sacral joint. A small sacro-iliac joint, the result of an abnormal first sacral segment, may not have sufficient area to stand even moderate trauma. A horizontal instead of a vertical lumbo-sacral joint has far less resistance to twisting strains. An X-ray study of the bone abnormalities in any case of painful back may provide a useful key to the diagnosis.

CHRONIC STRAINS

These are of two types. (1) Those resulting from frequently recurring acute traumatisms. (2) Those resulting from chronic bad posture with its inefficient weight-bearing line. Both lead to similar results.

In the sacro-iliac joint frequent recurrence of acute strains or sprains leads ultimately to chronic changes in the joint itself, just as such recurring strains do in the knee-joint. These changes are of two types—those occurring in the ligaments and synovia, and those occurring in the bone itself. The ligaments become relaxed and thickened, and lose a large part of their power to hold the joint in position. The synovia may become thickened and show fringes and fibrous tabs just as does the

synovia of the knee-joint. In the bone, chronic irritation leads to the formation of protective osteophytes which in themselves, by irritation of the nerves which cross the joint, may be the cause of pain down the course of the sciatic nerve. These facts are equally true of the lumbosacral and intervertebral joints.

The changes in the joints under the constant strain of bad posture are not so marked as those resulting from repeated trauma. They usually consist of relaxation of the ligaments, which makes the joint unstable.

It is difficult in the chronic cases to localize the cause of the symptoms, in any one joint, because there are invariably secondary changes in several of them. Careful X-ray examination will often demonstrate the presence of irritative osteophytes, and occasionally will show a marked thickening of the ligaments in the joint originally damaged.

The treatment of chronic cases of the first type is based on the treatment of chronic arthritis in other parts of the body. It consists essentially in more or less complete rest for a considerable period. This is to be carried out in bed at first, if necessary, and later by jackets, braces, or belts. Heat and massage are useful during the rest period. When the symptoms have disappeared, then carefully graduated exercises and passive motion to restore the tone of weakened muscles and ligaments, offer the best chance of permanent cure. It is difficult to restore completely any of these joints which have undergone organic changes.

The treatment of the joint disturbances due to the chronic strain of bad posture depends entirely on the correction of the standing and sitting positions. If the flat-footed, hollow-backed, round-shouldered individual can be taught to hold himself with his lumbar spine flat and his chest lifted, the bad weight-bearing line will disappear, and as a result the strain will go and with it the backache. This is a matter for the person skilled in corrective gymnastics, but must be carried out under the strictest surgical supervision in order to prevent exhaustion and over-strain. Much can be accomplished along these lines in reclaiming men who through bad posture are ordinarily too weak to stand the strains of army life. In the United States Army a start has been made in this direction through the formation of Reconstruction Camps, where men who have broken down because of weak backs and feet are sent for a course of drill and reconstructive exercises.

DISEASE

All the joints of the lower spine are subject to the various forms of disease which affect joints elsewhere. Tuberculosis, Neisserian infection, syphilis, bone tumours, acute and chronic arthritis of unknown infectious

origin, all occur. Of these, the most common is the chronic arthritis of the so-called ' hypertrophic ' type. This is always of gradual onset, and may or may not appear in connexion with similar disease in other joints of the body. The diagnosis is made from the history of gradual onset of pain in the lower back which varies in intensity and, gradually, over a period of years becomes worse ; on the gradually increasing stiffness of the lower spine as the joints become more and more involved, and on the X-ray appearances, which will show multiple spicules attached to the edges of the joints. This type of disease is very frequently accompanied by sciatica of greater or less intensity. This sciatica is the result of pressure by the bone spicules on various parts of the lumbo-sacral plexus.

The treatment of this type of arthritis is essentially partial fixation, which can be accomplished by belts or braces. Only in this manner can relief from pain be satisfactorily obtained. General medical treatment necessary to control the progress of the disease is also indicated.

The diagnosis of the other diseases and infections of the joints of the lower spine is made along the same lines of investigation that are used when they occur in other parts of the body. Their treatment is the same.

The foregoing lesions and disturbances of the various joints of the lower spine are some of the many which cause pain in the back. If they are borne in mind and carefully sought for, many otherwise obscure cases will be cleared up. Careful diagnosis along these lines will often make intelligent treatment possible and will prevent much unnecessary disability and suffering. Their discovery in individuals will avoid in many cases the vague diagnoses such as fibrositis, myositis, and rheumatism. On the other hand, it must always be borne in mind that there are many lesions outside of the articulations of the lower spine which cause pain. Among them are toxic neuritis from such causes as lead or alcohol, though these very rarely affect the distribution of one nerve only. Intra- and extra-spinal tumours of various sorts cause pain along the distribution of the lumbar and sacral plexuses. Abdominal and intestinal tumours do the same. All such causes of pain in the lower back must be ruled out before the diagnosis of joint lesion is made. They are, however, relatively rare.

In the study of these cases it is necessary to get rid of the old idea of the inherent stability and strength of the lower lumbar spine and the pelvic girdle, and to look on it as a particularly unstable and complicated mechanism with many and rather weak joints.

ILLUSTRATIVE CASES

Private A., admitted to hospital from training camp in February 1918. His history was as follows: One week before, he slipped while lifting one end of a heavy beam. Felt acute sharp pain in lower right back and a sensation as though something had ' snapped ' ; he was able with great difficulty to stand erect, and for fifteen minutes or so the pain was very sharp. It gradually wore off, and he was able to get about for the rest of the day till he went to bed with a lame back. Next morning he was unable to get up because of severe pain across the lumbar region spreading down over the right hip. He was allowed to rest that day and then urged to get up, and for the last five days had been limping about with constant pain. Examination on admission showed a strong young man who stood with his body tilted forward and to the right. There was very marked spasm of the lumbar muscles, especially on the right side. All back motions were very much limited, especially those toward the left. There was a marked tenderness and some fullness over the right sacro-iliac joint. No displacement could be made out. With the patient on his back, flexion of the right hip with the knee straight was very markedly limited and very painful. Rotation of the trunk on the pelvis was not much limited. X-ray examination was negative, except for the deviation of the lumbar spine due to spasm.

The patient was put to bed with a support under his lumbar spine and urged to persist in lying flat on his back. One or two doses of morphia were necessary to make this possible. At the end of twenty-four hours the pain, while the patient lay still, had entirely disappeared, but any movement caused recurrence. A firm strapping across the sacrum was applied and the patient was kept quiet for a week, at the end of which time he was able to sit up without pain. Two days later he was allowed out of bed, the strapping being held very tight. Gradually he was allowed to walk and at the same time massage and light exercises were instituted. At the end of two weeks more, the patient was discharged, having regained full activity. This case represents the simple type of acute sprain of the sacro-iliac joint.

Case 2. Capt. M., 45 years of age, of the medical department, when a young man, hurt his back while playing football and was laid up for some time with pain across the lumbar region. Since that time he has had recurring attacks of pain, often resulting from very slight injuries—so slight indeed that he has often not connected the injury with the pain and has considered that he had rheumatism brought on by a chill. Of late years the attacks have become more frequent and recently have been accompanied by pain down the sciatic on the right side. He has tried every known form of medicinal, electrical massage, and hydro-therapeutic

treatment, but has come to the conclusion that the only thing that cured the attacks was time.

He was first seen in August 1917 with a mild attack of sciatica. The pain was deep-seated at the lower end of the lumbar spine, slightly to the right. It forced him to limp and became worse on long standing : it was relieved in bed. Examination showed moderate deviation of the trunk to the right ; forward bending of the trunk was nearly normal, but rotation of the trunk to the left was very painful and much limited. A diagnosis of chronic recurrent strain or sprain of the right lumbo-sacral joint was made and a supporting corset-belt was applied, and the patient enjoined against active exercises. The condition cleared up promptly and did not recur so long as he continued to wear his belt. After six months, thinking he was entirely cured, he left off his belt : a few days later, in stooping over a wash-hand stand, his foot slipped, resulting in a sharp wrench of his lower back. There was intense pain spreading down the right sciatic, complete inability to straighten the body or to stand without support. For the next twenty-four hours the pain became more and more severe : he could neither lie, stand, nor sit in comfort and was forced to take several doses of morphia. Admitted to the hospital, the symptoms and signs described above were found to be present in much more severe form, and the X-ray showed a marked displacement of the right lumbo-sacral joint, which accounted for the pain down the sciatic. The patient was put to bed on a rigid plaster-of-Paris support and given sufficient morphia to keep him comfortable. At the end of forty-eight hours the spasm had relaxed, and the patient felt as though something had slipped back into place. Repeated X-ray examination showed the joint apparently normal. He was kept in bed until all pain had disappeared, and then given a plaster jacket and allowed to move about. After two weeks sciatic pain disappeared, but there persisted a paresis of the extensor muscles of the foot. Neurological examination showed a nerve disturbance entirely consistent with pressure at the point of emergence from the spinal canal.

This case represents a distinct slipping or partial dislocation of the lumbo-sacral articulation with pressure on the nerve root.

THE KNEE-JOINT

BY

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THE KNEE-JOINT

ANATOMY

THE knee is a modified hinge-joint in which the articular surfaces of the bones are not closely adapted to one another. In any position of the joint there is never more than a small area of the femur in contact with the tibia. A slight degree of antero-posterior movement and of rotation occurs in addition to the purely hinge-like action.

The joint depends for its strength mainly on the integrity of its ligaments, and, to a less extent, on the muscles which act upon it.

The knee-joint is composed of three separate articulations, two femoro-tibial and one femoro-patellar. The two crucial ligaments are the lateral ligaments of the femoro-tibial joints. The ligamenta alaria and ligamentum mucosum are the remains of the partition between the separate synovial cavities of this joint. Not infrequently one finds the ligamentum mucosum as a continuous sheet extending backwards to become continuous with the layer of synovial membrane investing the crucial ligaments, thus isolating the two lateral synovial cavities.

The Capsule. The capsule of the knee-joint is strongest on the posterior aspect of the joint, and it is quite a distinct structure on the inner and outer aspects. Antero-laterally it forms a thin fibrous layer closely applied to the outer surface of the synovial membrane, but above the patella and over the patella itself it is quite deficient.

On each side of the patella the capsule is weak, but the overlying lateral patellar ligaments, which are the aponeurotic expansions of the quadriceps tendon, give strength to the joint. Above and laterally, the capsular attachment is at least half an inch distant from the margins of the articular surface, so that portions of the non-articular surfaces of the femur are within the joint.

Posteriorly, the capsule is attached to the upper margins of the articular surfaces of the condyles and also to the inter-condylic line, and therefore the attachment practically corresponds to the epiphysial line. Below, the capsule is attached to the tuberosities of the tibia just beyond the margins of the articular surface.

The External Lateral Ligament is in two parts, a short posterior ligament attached to the spine of the fibula and spreading out to join the capsule, and a long external lateral ligament which along with the tendon of the biceps strengthens the outer aspect of the joint. The latter ligament is

a rounded cord extending from the external tuberosity of the femur to the head of the fibula, where it is attached between the two slips of the tendon of the biceps. It is entirely separate from the capsule of the joint, and is separated from the external semilunar cartilage by the tendon of the popliteus and a small intervening bursa.

The Internal Lateral Ligament is a very important structure, for it is intimately connected with the internal semilunar cartilage, and it plays a large part in the production of most of the internal derangements of the knee-joint. Superficially it is seen to be a long and somewhat strap-like band. At its proximal end it is attached to the femur near the adductor tubercle. It extends downwards and is attached distally to the upper part of the inner border of the shaft of the tibia behind the semitendinosus tendon. Its deep fibres are intimately connected with the capsule of the joint and are firmly attached to the peripheral border of the internal semilunar cartilage, and to the articular edge of the internal tuberosity of the tibia.

The Posterior Ligament, or ligament of Winslow, is a specially thickened portion of the capsule which assists in preventing hyperextension of the joint. It is formed by an expansion from the tendon of insertion of the semimembranosus and is directed upwards and outwards to the inner border of the external femoral condyle.

The Internal Semilunar Cartilage is semilunar in outline, and its two extremities are widely separated from one another. The anterior extremity or horn is attached to the front portion of the anterior non-articular area on the top of the tibia, and in addition it is connected by means of the transverse ligament to the anterior horns of the external semilunar cartilage. The posterior horn is attached to the posterior inter-condylic fossa just in front of the tibial attachment of the posterior crucial ligament.

The External Semilunar Cartilage is nearly circular in outline, and its extremities are attached close together. Its anterior horn is attached to the tibia immediately in front of the tibial spine. Its posterior horn is attached to the tibial spine and is connected both with the anterior and posterior crucial ligaments.

The peripheral border of the internal cartilage is firmly adherent to the internal lateral ligament, but the external lateral ligament is separated from the external cartilage by the popliteus tendon. On this account the external semilunar cartilage is more freely movable than the internal meniscus, although both are permitted a certain amount of movement to accommodate themselves to the articular surfaces of the bones in different positions of the joint. Both semilunar cartilages are thickest round their peripheral borders and thin away to their free central margins. They are thus triangular in transverse section. They consist of a core of fibrous tissue arranged transversely and longitudinally, with a covering

above and below of white fibro-cartilage. The longitudinal fibres are continuous at the cornua with the fibres attaching them to the tibia, and a few of these fibres are continuous in front from one cartilage to another to form the transverse ligament. At the convex border, fibres of the capsule blend with the transverse fibres of the matrix of the semilunar. The fibres coming from below are stronger and form the so-called coronary ligaments, which are really portions of the capsule between the semilunar cartilages and the tibia.

The Crucial Ligaments extend from the inter-condyloid notch of the femur to the non-articular area on the upper surface of the tibia. They are about the thickness of a small pencil, and are intra-capsular but extra-synovial.

The Anterior Crucial is attached above to the inner side of the external femoral condyle at its posterior part. It passes downwards, forwards, and slightly inwards to become fixed to the superior surface of the tibia in front of the internal tubercle of the spine, to the base of which a few of its posterior fibres are also attached. It may also have an attachment to the posterior horn of the external semilunar cartilage.

The Posterior Crucial springs proximally from the anterior part of the outer surface of the inner femoral condyle and passes downwards, backwards, and slightly outwards to the posterior rounded surface of the non-articular area on the superior surface of the tibia to which it is fixed.

The Synovial Membrane is complicated in arrangement, owing to the presence of the infra-patellar fat pad, the crucial ligaments, and the semilunar cartilages. It lines the deep aspect of the capsule, from which it is reflected on to those portions of the femur and tibia which are intra-capsular but not articular. In the pyramid formed behind and above by the condyles of the femur, behind and below by the tibia, and in front by the infra-patellar tendon, is lodged a pad of fat—the infra-patellar fat pad. This pad is extra-synovial but intra-capsular, and as it changes its shape with every movement of the joint, it fulfils the purpose of a buffer to protect the joint surfaces and also to fill in a hiatus that would otherwise exist in the joint. The synovial membrane is reflected over this fat pad and a triangular fold passes upwards and backwards to be attached by its apex to the anterior extremity of the inter-condylic notch. This fold is called the ligamentum mucosum. The free edges of this fold diverge and enclose the lateral margins of the fat pad. These free edges are known as the ligamenta alaria or the alar folds. Both femoral and tibial surfaces of the semilunar cartilages are covered by synovial membrane. The synovial membrane is reflected off the centre of the posterior ligament at each side of the posterior crucial ligament. It covers both crucial ligaments in front and at the sides, so that they are both extra-synovial.

The muscles acting on the joint are extensors—flexors and rotators. The quadriceps is a very important factor in maintaining the strength of the joint and through its sesamoid—the patella—forms an integral part of the articulation.

The patella, the ligamentum patellæ, and the lateral patellar ligaments cover in the entire anterior part of the joint and give it strength. On account of these intimate relationships it is obvious that the tone of the quadriceps is of great importance.

The hamstrings as a whole prevent over-extension of the joint, the biceps in addition giving strength to the outer side through its relationship with the external lateral ligament. The semimembranosus and semitendinosus strengthen the inner side. As well as being flexors, they act to a slight extent as internal rotators.

MECHANISM WITH REGARD TO DERANGEMENTS

The movements of the knee-joint are two, an antero-posterior hinge-like movement, and also rotation of the tibia upon the femur. In the movement of extension the condyles move parallel to one another, both gliding and rolling until extension is nearly completed. When the anterior part of the rolling surface of the external condyle has already come into full contact with the tibia, the femur, when the tibia is fixed, rotates inwards on the latter and extension is complete. Each semilunar cartilage assists the opposite lateral and crucial ligament in resisting lateral movements of the leg, for it acts as a wedge between the tibia and femur and helps to make the crucial ligaments tense. In no position of the knee is lateral movement allowed, this is prevented by the wedge-shaped semilunars, during extension and slight flexion by the lateral ligaments, and during the more acute flexion by the crucial ligaments. It is evident that in addition the musculature aids very considerably in strengthening the knee, but both quadriceps and hamstrings are quite inefficient as substitutes for either the crucial or lateral ligaments should these be put out of action. It should be realized that the stability of the knee-joint depends upon the integrity of the capsule of the joint and its reinforcements, the posterior and lateral and crucial ligaments, and also of the muscles acting on the joint through their aponeurotic expansions. The semilunar cartilages, as stated above, act purely mechanically by reason of their wedge-like formation. The most important of all ligaments are undoubtedly the crucials and from the mechanical standpoint nothing could be more beautiful and efficient than the action of these ligaments in stabilizing the joint. Each and every one of the structures mentioned above is dependent upon the other. The crucial ligaments stand a large amount of strain in any forced movements of

the joint. The anterior crucial becomes tight when the joint is extended, becomes slack in semiflexion, and tense when the joint is fully flexed. The posterior crucial is tight in full flexion, becomes slack in semiflexion, but with the joint in full extension it again appears to become tense. It is thus seen that in full extension and flexion of the joint both the crucials prevent antero-posterior movement at the joint. The amount of tension is relaxed when the knee is semiflexed, as can be easily demonstrated by forcibly pulling and pushing the head of the tibia in an anæsthetized person. It is found then also that the amount of sliding of the tibia on the femur is very slight.

Extension of the joint is limited by the hamstring muscles, the posterior ligament of Winslow, the lateral ligaments, the anterior crucial and posterior crucial. The most important are the posterior ligament of Winslow and the anterior crucial.

Rotation is prevented in the fully extended position by all the ligaments that limit extension. In semiflexion a certain amount of rotation both inwards and outwards is possible. Internal rotation is allowed on account of the relaxation of the anterior crucial and the internal lateral ligaments. Competent anatomists are of opinion that internal rotation is chiefly limited by the crossing of the crucial ligaments, the anterior pressing on the tightening posterior. External rotation in the semiflexed position is comparatively free ; it is limited by the superficial fibres of the internal lateral ligament to a certain extent, but mainly by the deep attachment of this ligament to the internal semilunar cartilage (the suspensory ligament) and the attachment of its deep short fibres just beyond the articular edge of the tibia. The anterior crucial and the external lateral ligaments have no limiting action at all.

Adduction of the knee is limited by the external lateral and posterior crucial ligaments aided by the wedge-like internal semilunar cartilages.

Abduction of the knee in the fully extended position is limited by all fibres of the internal lateral ligament. When the knee is flexed more than 20°, the long superficial fibres pass out of action, and the main source of stability is now the deep division of the internal lateral and the anterior crucial ligaments.

Lateral sliding of the knee is prevented by the crucial ligaments, the semilunar cartilages, by reason of their wedge-like shape, and in addition by the attachment of the internal meniscus with the deep fibres of the internal lateral ligament.

If the internal lateral ligament be divided, the extended limb can be appreciably abducted and the articular surfaces of the tibia and femur correspondingly separated.

The commonest form of knee sprain is caused by combined abduction of the knee with external rotation of the tibia, the knee being in the semi-

flexed position. Should the foot be fixed on the ground, rotation of the femur inwards on the fixed tibia acts in the same way. The strain upon any ligament is more severe when it is twisted as well as stretched. A twist takes place when the knee is semiflexed, the foot abducted, and the femur rotated inwards on the tibia. It is in this position that strain and rupture of the internal lateral ligament and displacement of the semilunar cartilage almost always occurs. The deep fibres of the internal lateral ligament attached to the internal semilunar cartilage and to the edge of the tibia become torn and the cartilage becomes displaced inwards, and may or may not be fractured or crushed by the articular surfaces of the bones when they come together after the mechanical forces are removed. Should the forces continue to produce further abduction of the knee, the entire strain is borne by the anterior crucial ligament, which in its turn may become stretched or torn, or the internal tubercle of the spine of the tibia may become avulsed. If the forces begin to act while the knee is extended, the superficial fibres of the internal lateral ligament are bound to suffer ; but if, as is usually the case, the knee be in slight flexion when the accident occurs, these fibres will escape.

STRAINS

Strains at the insertions of muscles in the neighbourhood of the knee-joint may occur in the young soldier during his hardening process. The biceps—semimembranosus and semitendinosus—are those most likely to suffer. The condition is diagnosed by pain on palpation over the insertion of the muscle, this pain is intensified by making extension of the leg against the resisting muscle. Treatment should consist in applying a garter of adhesive strapping encircling the limb above the patella. This, along with an addition of half an inch to the heel of the boot to prevent stretching of the sprained muscle, should be sufficient to bring about cure of the condition.

Periostitis at Muscular Insertions may occur if the strain be untreated.

OSGOOD'S DISEASE [Schlätter's Disease]

The proximal epiphysis of the tibia unites with the shaft at about the twenty-fourth year. Occasionally there is a separate centre for the tibial tuberosity which appears about the twelfth year and about a year later fuses with the rest of the epiphysis. Avulsion of the tibial tuberosity may occur in youth before the completion of ossification and is due to excessive muscular strain. Minor degrees of this accident may cause a partial separation of the tuberosity with marked irritation at the epiphyso-diaphyseal junction. The condition may become chronic owing to repeated strains and want of rest, the condition being known as Osgood's

disease. Although the condition is not common after the seventeenth year it does occasionally exist in young soldiers of the eighteen-year-old class. A history is given of the knee giving way at times, combined with inability to march long distances and pain in front of the knee is complained of. A fullness at the sides of the infra-patellar tendon is found, and there is much pain complained of on palpation of the insertion of the tendon. A slight limp is present, less marked after resting. One boy recently seen in a military hospital, had been diagnosed as an internal derangement of the knee. Treatment should provide rest to the quadriceps, which should never be allowed to contract fully. The heel of the boot should be raised half an inch and a supra-patellar garter of adhesive strapping should be applied to prevent undue action of the quadriceps and so minimize the recurrent strains on the tendinous insertion that produce the irritation at the epiphysis.

SPRAINS

From the military standpoint, sprains in the region of the knee-joint are of great importance. The lateral ligaments are those that are most apt to suffer, and in the vast majority of cases the internal lateral ligament is affected. Mechanism producing this injury has been explained in the previous paragraphs. Football played on muddy fields while wearing ammunition boots claims many victims. Trench warfare with its accompaniment of mud, slippery duck-boards, and shell holes, presents many pitfalls for the unwary knee-joint. The internal lateral ligament is subjected to strain whenever the foot is firmly planted and the knee abducted while extended or slightly flexed. If, in addition to this, body weight with internal rotation of the femur is added, the strain on the ligament is produced which is so harmful to its integrity. It may be stated that the strength of the knee-joint is proportionate to the strength of the internal lateral ligament.

A displacement or fracture of the internal semilunar cartilage cannot occur unless the internal ligament be stretched or ruptured. The degree of force applied decides the question as to whether the ligament be sprained or ruptured and whether the cartilage escapes injury or not. The question as to the involvement of the internal semilunar cartilage depends very largely on the position of the lesion of the internal lateral ligament ; if the latter be stretched or torn above the level of the joint, the cartilage remains intact on the tibia, if the ligament be torn below the level of the joint, the cartilage will be pulled upwards by its suspensory ligament and will follow the rotatory motions of the femur. The cartilage will become displaced, and as the articular ends of the joint are separated on the inner side by reason of the abduction of the knee, the cartilage

will tend to slip inwards towards the centre of the joint. As the separated bones snap together, the cartilage becomes nipped and the knee locks in a painful manner ; the pain and effusion that follow can be ascribed to the injury of the synovial membrane with which the cartilages are covered. It is necessary to enlarge on this point to impress upon the reader the close relationship of the internal lateral ligament and injuries to the semilunar cartilage, as it is merely a question of the degree of strain as to whether the cartilage escapes injury or not. It is very necessary in dealing with these cases to diagnose as to whether the lesion is in the ligament alone. Effusion may occur as the result of a sprain of the internal lateral ligament without cartilage complications. It may also occur in so-called simple football knee, which is probably due to damage of the synovial membrane by direct violence without ligamentous injury. The commonest type of sprained knee is accompanied by effusion —here the injury is located in those fibres of the internal lateral ligament which are attached to the upper articular margin of the tibia. Should the fibres of the internal lateral ligament be torn from their femoral attachment it is possible that effusion may not be present, should the synovial membrane escape injury. All cases of sprains of the internal lateral ligament with effusion into the joint but unaccompanied by locking should be regarded with grave suspicion, as damage to the internal semilunar cartilage may well be present. Palpation of the damaged ligament will be productive of excruciating pain at the site of the damage.

Treatment must aim at healing all the torn ligaments without stretching, this entails immobilization of the joint in the adducted position. The limb should be rested on a back splint for two or three weeks, to allow the effusion to subside ; and daily massage will assist in the absorption of the effusion. The patient may be allowed to walk at once, provided the boot is altered so as to throw all the strain on the outer side of the knee. This is easily done by raising the sole and heel of the boot on the inner side. Should there be no effusion as an accompaniment of the sprain, strapping of the inner side of the knee combined with the altered boot will be all that is required.

Sprain of the external lateral ligament is a much rarer injury and is not so severe in its effects. It is produced by adduction and rotation inwards of the knee, and is never complicated by damage to the external semilunar cartilage, and is not usually accompanied by effusion into the joint. It will be remembered that the external semilunar cartilage is separated from the capsule by the tendon of the popliteus, and also that it is more loosely moored to the tibia than is the internal meniscus. For this reason it adapts itself to the various rotatory movements of the joint and is rarely damaged on this account.

SPRAIN FRACTURES

Sprain fractures of the lateral ligaments are merely a variety of the above and are produced by the same mechanism. The internal lateral is generally ruptured at its femoral attachment. X-rays show a small bony film separated from the femur in the region of the adductor tubercle. The treatment is the same as for sprain of the ligament with the exception that the limb should be immobilized for a longer period of time, preferably for about four weeks. A sprain fracture of the deep fibres of the internal lateral attached to the tibia may occur. When this happens, a plate

FIG. 124.—A. Articular surface of tibia. B. Suspensory ligament. C. Internal semilunar cartilage.

of bone including part of the articular surface of the tibia in the vicinity of the ligament becomes separated. In such cases the internal semilunar cartilage remains attached to the separated bone by its suspensory ligament and lies within the joint together with the portion of the tibia that is torn off. This type of case is much more serious than the previously mentioned variety. It is probable that the lesion caused by forces producing sustained abduction at the knee, by reason of the extreme violence, has been such as to stretch or rupture the anterior crucial ligament. Operative treatment may be required to pin the free piece of bone, to remove the semilunar cartilage which will have been ruptured at its anterior horn, and possibly to suture the anterior crucial or make a fascial substitution. If the free piece of bone and cartilage are merely removed (Fig. 124), the symptoms of periodic locking of the joint which are always present will be cured, but the antero-posterior mobility

of the tibia on the femur and sense of insecurity by the patient due to the anterior crucial injury will be exaggerated.

Sprain fracture may occur at the external lateral ligament. As a rule this ligament becomes separated at its femoral attachment, although this is by no means constant. A flake may be torn from the head of the fibula. In treatment of this injury, body weight must be deflected to the inner side of the joint in addition to immobilization. It is well to remember that the posterior crucial ligament may have been stretched in addition. Should this be so, the heel should be raised half an inch as well as being built up on the outer side in order to prevent hyper-extension of the knee-joint. Operative interference will rarely be required unless the crucial injury warrants it. The operation will be that described in the section dealing with the surgery of the crucial ligaments (q. v.).

CARTILAGE INJURIES

Injuries to External Semilunar Cartilage. Injury to the external meniscus is a comparatively rare occurrence, and in the experience of Sir Robert Jones does not constitute more than 8 per cent. of the total number of cases. This is due to the fact, to which previous reference has been made, that this external meniscus is more loosely moored than the inner one and is allowed a certain degree of independent movement during rotation of the femur on the tibia.

Injuries to the external semilunar cartilage may give rise to varied symptons which are sometimes difficult to diagnose. Occasionally there is a definite locking, but as a rule the symptoms complained of are more in the nature of a transitory catch or slip referable to the outer side of the joint. Some cases present a snapping or clicking sound in full flexion and extension of the joint ; it is more frequently experienced when extension is all but complete. If the surgeon places his hand on the patient's knee and asks him to extend his leg, this is found to be done perfectly until the leg is about 10° short of full extension. A transitory catch now occurs and full extension is performed suddenly, accompanied by a clicking noise and by an outward rotation of the tibia. It is advisable to palpate very carefully between the bones in front of the external lateral ligament while extension is taking place. An abnormal disturb-ance is felt to occur beneath the examining finger.

Injuries to the Internal Semilunar Cartilage. Injuries to the inner meniscus constitute the great majority of all cartilage cases. This is due to the following reasons :

(*a*) The meniscus is more firmly attached to the tibia than is the external cartilage.

(*b*) In the standing position body weight falls through the inner side of the knee-joint.

(*c*) The shape of the internal articular surface of the tibia allows the internal condyle of the femur to glide backwards on the tibia. The range of internal rotation of the femur on the tibia, which movement causes a direct strain on the semilunar, is thus greater than that of external rotation.

While the usual cause of the cartilage lesion is strain thrown on the internal lateral ligament when the knee is slightly flexed and the femur rotates inwards on the fixed tibia, in rare cases the displacement may occur while the knee is fully extended.

Martin has called attention to the frequency of the occurrence amongst north-country colliers working with flexed knees in low seams in the mines. A wrench or forcible twist of the tibia on the femur whilst crouching with the knees bent, tends to produce a tearing of the semilunar cartilage.

Sometimes symptoms of an internal semilunar injury may be referred to the outer side of the joint as at operation the external meniscus is found to be intact.

In the vast majority of cases there is nothing abnormal to be felt in the external examination of a knee subject to recurrent attacks.

In practically all cases the cartilage is displaced towards the centre of the joint, and in those rare cases where a protrusion is felt between the bones on the surface of the joint, the mass is due either to bruising and hæmorrhage or to a split or buckled cartilage which is acting as a pedunculated loose body. It is obvious from the anatomical standpoint that a wedge-shaped disc displaced outwards cannot produce a locking of the joint, but a portion of the cartilage may have become separated and be acting as a loose body.

The most constant symptom of a displaced or fractured semilunar is a sudden inability to extend the joint. As a rule this locking comes on immediately after the injury, but less frequently no such locking occurs at the outset. Many cases have been seen in which the patient has been certain that no locking occurred at the time of the accident, but definite locking has occurred at varying periods later. This may be explained by the fact that the forces acting on the joint have torn fibres of the internal lateral ligament and no more, and that subsequent mechanical indiscretions, acting on an imperfectly healed ligament, have produced the dual lesion of a ruptured internal lateral ligament and damaged cartilage. Sometimes there is a sensation at the time of injury as of something slipping in the joint but without any locking—here the cartilage has been probably bruised and has slipped back into place.

In the initial injury the force necessary to cause the derangement is usually severe and the pain is extremely acute. A man heavily equipped may slip sideways on a duck-board or may trip into a shell hole, the foot may be stabilized, the knee flexed somewhat, superincumbent body weight rotates the femur inwards, and the man falls to the ground with a sudden cry or exclamation of pain. When he tries to rise or is helped to a standing position he finds that he cannot straighten his leg, and that the putting of any weight on the foot is very painful. The medical officer finds that there is marked effusion into the joint and that any manipulations cause extreme pain. The leg can be voluntarily flexed, but any attempt to extend the knee beyond an angle of 30° from straight is impossible on account of an intra-articular interference and the pain produced. This is the usual type of case where there is definite locking caused by the cartilage being split or broken and part of it is nipped between the bones.

In cases where locking has not taken place effusion will be present, as well as pain—on palpation over the site of the most accessible portion of the cartilage—which can be felt on the upper edge of the tibia half an inch to the inner side of the internal border of the infra-patellar tendon. Abduction of the knee will also be found to be freer than it should be, and manipulation necessary to elicit this symptom will be productive of much pain.

Treatment. If the joint is found to be locked it is necessary to reduce it at once. In a recent case the manœuvre will, as a rule, be a fairly simple one, but this is not always so. Sometimes two or three attempts will be required, and if the knee is not seen for two or three weeks after the injury, the full reduction may be an operation of some difficulty requiring the use of a general anæsthetic.

In recent cases it is advisable to attempt reduction without the use of an anæsthetic, but the assistance of the patient is necessary.

The leg should be firmly but gently flexed well into the ham, one of the surgeon's hands should be placed stirrup-wise beneath the sole of the foot, and during the process of flexion the foot should be rotated inwards as much as possible. The other hand of the surgeon should be placed over the patella during the manœuvre, and at the word of command the patient should be instructed to kick his leg out as hard as possible, at the same time the surgeon should assist this movement forcibly by pressure on the patella. The operation is much simplified by making the patient extend his leg, as otherwise the surgeon may be hampered by spasm of the hamstrings. If the cartilage is fully reduced the patient is aware of the fact, as he can feel something slip within the joint ; this is also felt by the surgeon's hand. Displacements of several weeks' standing have been satisfactorily reduced by this method. If reduction is complete

the leg is found to extend fully without any difficulty. Should full extension be not possible, one can take it for granted that the cartilage is not completely replaced and the procedure must be repeated. Partial reductions mean constant bruising of the nipped portion and are productive of recurrent effusions with symptoms similar to those produced by a bruised infra-patellar fat pad, only more acute than the latter.

In all recent displacements that have been fully reduced—that is to say when the knee can be fully extended without pain—complete rest to the joint should be ensured until the torn attachments have united. The knee should be kept fully extended on a back-splint for at least ten days (during which time the patient should be in bed or on a couch), the bandage being firmly applied over cotton-wool to produce elastic pressure on the swollen knee. Paracentesis may be required to relieve intra-articular tension.

After ten days the splint can be discarded and the patient may be allowed to walk with his boot raised sole and heel on the inner side. A firm bandage should be applied over the knee to prevent effusion into it and massage of the knee and thigh with faradism to the quadriceps should be practised daily. Movements of the joint should be restricted for the first week that the patient walks—the bandage can be removed after ten days but the altered boot should be worn for another month. If the movements of the joint are gradually increased and the tone of the quadriceps muscle correspondingly improved no recurrence of effusion should take place. In the majority of cases so treated the cartilage should become fixed down by adhesion and no recurrence should occur.

The cartilages can only be retained in a fixed position when the limb is fully extended. In all rotatory and lateral movements of the joint the cartilages take part, so the initial course of treatment by rest is imperative.

In Military Orthopædic Hospitals one does not often see a case *de novo*, but cases are sometimes sent there complaining of recurrent effusions following a knee-joint injury in which no locking had taken place. It is usually found that the preliminary treatment by fixation of the joint has been deficient. Effusion has taken place when the patient was allowed to walk after possibly a few days' rest in bed. Probably the attachments of the anterior horn of the cartilage had originally been torn, and because of premature joint-movement the newly forming cicatrix has stretched. Here one expects a history of periodic 'givings' in the joint accompanied by effusion.

Sometimes the cicatrix becomes so thickened by reason of the periodic irritation that it can be felt on palpation over the position of the anterior half of the cartilage. This 'diagnostic spot' before mentioned will be extremely painful and an extraneous mass will be palpable. The thickened scar may become so large as to produce a definite locking when the knee

is fully extended. Removal of the whole mass with the anterior half of the cartilage is required.

Our pre-war views as to when to operate on semilunar cartilage injuries have had to be modified somewhat in view of the exigencies of military service.

Cases coming to orthopædic centres diagnosed as derangements of the knee-joint should be carefully examined with a view to determining as to whether a single derangement has occurred or whether the case is a recurrent one. In many cases athletics of the pre-war era have been responsible for the initial injury, and a second or subsequent locking has taken place during training or overseas service. Operation is always indicated in this class of case.

Where no definite history of locking is given and where there is no recurrent effusion, cases on arrival should be sent to the gymnasium for vigorous training. Few knees survive this test if the cartilage is at all insecure. Should the knee develop symptoms of derangement the cartilage should be removed in order to increase the man's efficiency from the military standpoint.

Despite the fact that recent teaching with regard to knee-joint surgery shows that the joint has resistant properties far beyond what it was previously thought to possess, it is necessary to emphasize the necessity for observing the very strictest asepsis in operations on the knee-joint.

A case admitted to an orthopædic centre last year was operated upon in 1915 and nearly two years later was still bedridden with a network of incisions on both thigh and leg secondary to acute arthritis of the joint. Further remark is needless.

Operation on the Internal Semilunar Cartilage. The knee-joint should never be opened except under the most scrupulously aseptic conditions, i.e. in a theatre reserved for aseptic cases. Careful local preparation of the skin is required. This entails two ward preparations, twenty-four and twelve hours previous to the operation, and at the end of each the field of operation should be covered over with sterile towels. The first preparation should thoroughly cleanse the part. The aim of the second preparation is to supplement the first one and in addition to produce dehydration of the skin—this can be well brought about by thorough rubbing with a spirituous solution of biniodide of mercury. The sister who makes the preparation should do so with rigid asepsis, and she should wear gloves.

At the operation a tourniquet is applied to the thigh, and the leg to be operated upon is flexed over the end of the table. The other leg is allowed to hang over the side of the table, and is tied there so as to be out of the way of the operator. The affected foot and leg should be covered in by a separate towel which should be wrapped closely around

the limb—this should be outside the other sterile draperies. This point is of importance in case the surgeon wishes to have the foot and leg rotated during the operation. The field of operation is painted with a 3 per cent. solution of picric acid in alcohol or with tincture of iodine.

With the knee flexed to a right angle a curved incision is made two inches in length. The incision which involves the skin only begins a ¼-inch internal to the inner edge of the patella at its centre. The cut curves downwards and backwards for one inch until it reaches the level of the joint, and for the remaining inch it runs parallel to the upper articular surface of the tibia. Small wound towels are now clipped to the edge of the wound ; these should shut off all the field of operation not previously covered in. The knife that has been used for the skin incision should be discarded to prevent any likelihood of infection from the skin. A fresh knife is taken and the lateral patellar ligament is divided by a similar incision to that described for the skin. Great care is required not to prolong this incision so far posteriorly as to endanger the anterior fibres of the internal lateral ligament. A fatty layer on the outer side of the capsule is seen and several small vessels are divided which are liable to ooze in a troublesome manner if the tourniquet be not efficiently applied. The joint is opened and two small retractors separate the line of incision into the synovial membrane. A blunt hook can now be slipped under the free margin of the cartilage, and it can easily be seen whether the front part is detached or split or has tags or projections liable to cause disability. The alar ligaments should be carefully inspected as to whether any fringes are present in the neighbourhood of the cartilages that might be liable to cause symptoms. Should there be a definite lesion in the front part of the cartilage, I think it is sufficient to remove the anterior half of the meniscus, but it is obvious that for this to be deemed sufficient all the damaged portion must be removed and the circumferential attachment of the retained portion must be intact.

In cases where there is no definite lesion to be seen in the anterior portion, the whole of the cartilage should be removed. The anterior horn should be detached and this should be impaled with a sharp hook. The circumferential attachment of the cartilage should now be divided by means of a fine-bladed knife, traction being applied by means of the sharp hook. In order to facilitate the separation of the posterior portion of the cartilage the leg should be rotated outwards. If the surgeon sits on a low stool facing the end of the table in order to perform the operation, external rotation can be made by pressure of the surgeon's knee against the patient's foot. Where the lesion is found to be a splitting or loosening of the posterior part of the cartilage the operation is simplified as gentle traction brings the offending portion away. It is sometimes necessary for an assistant to bring the tibia forward on the femur to complete

the removal of the cartilage whenever difficulty is experienced in dividing the posterior attachments.

In removing the cartilage, care should be taken that no tags, liable to cause subsequent trouble, are left projecting from the coronary ligament.

The capsule and lateral patellar ligament should be carefully sutured in two layers by means of fine catgut of reputable make, the skin being sutured without drainage. The dressings are applied with the knee in the flexed position and the limb is extended to enable one to apply the sterile bandage. A certain amount of elastic pressure is applied to the joint by means of bandaging over large pads of absorbent cotton. The tourniquet is now removed. A back-splint of sufficient length to completely immobilize the knee is applied by means of adhesive strapping in addition to bandage. The former is required to prevent lateral sliding of the splint during convalescence. It is to be noted that ligation of no vessels is required at the operation. The patient is kept in bed for a week, after which time the stitches are removed, he is then allowed to walk a little with the back-splint. At the end of a fortnight the splint is removed, massage and faradism to the quadriceps is begun, and the patient walks with a bandaged knee and is allowed gentle active movements. The range of movement is increased each day, and at the end of the third week the bandage should be discarded and the patient should walk with freedom and a full range of movement. No case is ready for full military duty for at least six weeks after the operation, and it is my custom to prescribe a short course of electrical and gymnastic treatment to bring the quadriceps into a condition of normal tone before the case is sent to his depôt. It is necessary to add that a certain percentage of men complain of vague pains after operation for which no satisfactory reason can be attributed. Such cases are referred to Command Depôts. Recuperative training under strict military discipline appears to be the most satisfactory way of dealing with the type of man who obviously does not want to shorten his convalescence.

It has been suggested in certain quarters that the split patellar route is the operation of choice for all derangements of the knee. From the military standpoint this operation should never be undertaken for the simple removal of a cartilage. Cases have come into my hands six months after such an operation showing signs of villous arthritis of such severity that the patient was not fit for a higher category than sedentary duty at home.

Operation for removal of the External Meniscus. Where a diagnosis of injury to the external semilunar cartilage has been made, a corresponding incision to that above described, but on the outer side of the joint, can be employed.

In cases where the certainty of the diagnosis is in doubt it has been my

practice to make the usual incision on the inner side so that a complete examination of the inner meniscus can be made. This cannot be done from an external incision, although a fair view of the external cartilage can be obtained from the internal incision by means of a speculum type of retractor. I have on two occasions found simultaneous damage to both cartilages and have removed the damaged anterior portion of the external meniscus through the internal incision.

Fig. 125.

OSTEOMATA

Osteomata in the region of the knee-joint are of interest in that they may give rise to symptoms very like those displayed in internal derangements. Exostoses are the commonest extrinsic cause of mechanical derangements of the knee. The joint may become locked or obstructed by the slipping of muscle or tendon over the exostosis. The patient may complain of 'a knee which slips at the back'. The symptoms nearly always occur when active or unusual exercise is being performed. The knee sometimes locks completely in flexion and when this occurs it is often difficult to reduce. As a rule, however, the symptoms are not so acute, there is merely a feeling of insecurity at the back of the joint. The patient may fall to the ground, but after manipulating the back of

his knee he finds he can extend his leg again and carry on with his athletics. Sometimes it is the biceps that is hampered, at other times the inner hamstrings, and cases are on record where a pedunculated exostosis has become entangled in the outer head of the gastrocnemius. Where the exostosis arises on the inner side of the tibia near the epiphyseal margin and comes in contact with the sartorius and semitendinosus, symptoms suggestive of internal semilunar injury manifest themselves (Fig. 125). There should be no difficulty of making a diagnosis, an X-ray picture will clear up the condition, but in addition to the fact that the mass can be palpated, there is never any synovitis in connexion with the locking that is complained of. It is only rarely that osteomata give trouble, and many knee-joint radiograms show them to be present in the region of the joint without any symptoms having manifested themselves.

Treatment. Whenever an osteoma causes symptoms it should be removed. This is a rule easily carried out by dissection and subsequent chiselling through the neck of the growth. Occasionally the growth is of such extreme hardness that its division by means of mallet and chisel is of greater difficulty than one might be led to expect.

LOOSE BODIES

Loose bodies in the knee may be extrinsic or intrinsic in origin. Those intrinsic in origin may be fibrinous loose bodies or they may be composed of bone or cartilage. Extrinsic loose foreign bodies, in military surgery, are generally composed of some missile such as bullet or fragment of shell.

Fibrinous Loose Bodies. These bodies consist of laminated masses of fibrin which Kœnig originally described as ' corpora oryzoidea ', but known to English-speaking surgeons as rice bodies. They may exist in joints, in bursæ, or in tendon sheaths, and may be indicative of tuberculosis. In joints they may exist in large numbers, and in the knee-joint one has seen cases where the supra-patellar pouch is full of these masses as a melon is full of seeds. They do not give rise to symptoms of locking or slipping such as are produced by loose bodies of the more highly organized tissue group ; this is possibly due to the tension that is produced within the joint by their presence. These masses are the result of disease in the synovial membrane, and are probably produced by the extra amount of fibrin thrown out by the synovial cells becoming rolled into rounded masses.

The patient may complain of stiffness of the joint and the extremes of flexion and extension will be lost as regards movement.

In the knee-joint the treatment of this condition is merged in the treatment of the disease which produces it. It is not common in the soldier, and I have had only one case brought to my notice during the present war.

Loose Bodies composed of Bone or Cartilage. These bodies are the result

of trauma to the joint. As a rule they are caused by an injury to the inner edge of the femoral trochlea. The piece of cartilage that becomes chipped off may or may not possess a core of epiphyseal bone. The loose body now wanders in the joint and apparently obtains sufficient nutriment

FIG. 126.

from the synovial fluid. It tends to grow and during its peregrinations it becomes rounded and entirely covered with cartilage.

A type of loose body has been described by many writers under the heading of osteochondritis-dissecans. A certain group of persons suffering from this disease display a tendency to the formation of loose bodies after a very slight injury to the knee (Fig. 126). The pathology and ætiology of these bodies still appears to be in dispute. Trauma appears to be the more generally accepted ætiological factor. Others state that these bodies are due to necrosis from injury and thrombosis of one of the terminal arteries

of the femoral condyle. The necrosed cartilage exfoliates. The bodies in this condition rarely number more than two or three.

FIG. 127.

Multiple loose bodies often exist as the accompaniment of rheumatoid arthritis (Fig. 127). These are caused as a rule by trauma, the hypertrophic edges of the bone at the chondro-osteal junctions in the joint becoming

separated. Whitelocke believes that fibrous tags on the synovial membrane that occur in hypertrophic rheumatoid arthritis may become cartilaginous. The development of cartilage in this fibrous tissue is due to the fact that during development, the articular and intra-articular cartilages of the knee-joint are all derived from the same primitive embryonic layer.

Loose bodies may occur as the accompaniment of Charcot's disease. The diagnosis of a Charcot knee by reason of its painlessness, swelling, and preternatural mobility should not be a matter of difficulty. The loose bodies rarely cause trouble and should never be operated upon.

The diagnosis between a damaged semilunar cartilage and a loose body of cartilaginous origin, more especially if the latter be pedunculated, is a matter of great difficulty and often an impossibility. Should the loose body be pedunculated, symptoms may be identical with those of a damaged semilunar cartilage. Locking takes place accompanied by effusion into the joint. Very often symptoms are referred to the anterior horn of the internal semilunar cartilage. Where the loose body is lying free in the joint, the symptoms of catching or locking are generally transitory in character. They are referred to different locations in the joint and are produced with the leg in varying positions. Very often, after many recurrences, the patient can, by manipulating the joint, bring the loose body to the periphery, where it can be felt by the examining finger. Should there be a bony matrix in the loose body, diagnosis by means of the X-rays is usually possible.

The treatment for all loose bodies, with exceptions as stated above, is by operation and removal. Where the body does not wander and is probably pedunculated, the operation is practically the same as for removal of the internal semilunar cartilage. Where the body tends to disappear and reappear at different portions of the joint, it is advisable to localize and fix it previous to the operation. This should be done immediately before the anæsthetic is administered, as the patient's help may need to be invited. His hands should be sterilized and he should wear a mask and gloves, and by manipulating his leg he should bring the body to a superficial position, where it should be placed in the keeping of an assistant. The knee should be kept extended during the operation. It is found advisable to fix the loose body, when it is manœuvred into a satisfactory position, by means of a strong Hagedorn needle. If the body is of a fair size the crucial ligaments will prevent its wandering into the posterior recesses of the joint.

In rheumatoid arthritis of the hypertrophic type loose bodies lying in the anterior compartment of the joint should be removed by means of the split patellar operation. Loose bodies lying in the back of the joint should be removed by means of a vertical posterior incision in the centre

of the popliteal space. The internal popliteal nerve and vessels are retracted to the outer side and usually the loose bodies can be felt through the capsule. As stated above, by reason of the narrow channels connecting the anterior and posterior portions of the joint, such loose bodies are not apt to travel out of the posterior compartment if they are of any size.

Loose bodies in this position must be differentiated from sesamoids in the origin of the gastrocnemius. The latter are oval or scaphoid in shape with the long axis vertically, usually single, but two may be present. Radiographically they are often quite dense and show definite trabeculation. They are always situated posterior to a line drawn from the posterior border of the femoral condyles to the posterior border of the upper surface of the tibia.

To sum up, loose bodies may be produced in the knee-joint in any one of three ways:

1. *By trauma—as a rule by falling on hard ground with the knee flexed.*—A chip of cartilage is removed from the internal condyle of the femur by direct violence; possibly this cartilaginous chip may contain a portion of the underlying bone. The loose chip may remain pedunculated for any length of time or may immediately lie free in the joint.

2. *By osteochondritis-dissecans.*—A mild degree of trauma is a factor in these cases; a certain area of cartilage and bone may desiccate and become a loose body. Bodies formed in this manner may be multiple, but they do not usually exceed two or three in number (Brackett). They exfoliate from the condyles of the femur, usually the internal one. When such a loose body is removed, it is not uncommon to find a scar on the area from which it has sprung; a hiatus is seen in the cartilage which may be partially or wholly filled with fibrous tissue.

3. *As a result of hypertrophic rheumatoid arthritis.*—These are multiple, and are caused either by the breaking off of hypertrophic nodules of bone due to trauma or by the chondrification of fibrous tags from the synovial membrane.

Foreign Bodies of Extrinsic Origin. In pre-war days needles were the most usual foreign bodies found, which were introduced either by accident in children or by design in neurotic adults. Such a case in a soldier was brought to my notice where the man had evidently pushed one of the needles from his 'housewife' into his knee-joint. If the man's intention was to avoid service overseas, his scheme was unsuccessful.

It is not often that one sees a war wound of the knee-joint in which lodgement of the foreign body, in or near the articulation, has occurred without septic manifestations.

Occasionally a lodged bullet may lie quiescent and only cause symptoms mechanically by reason of its interference with extension and flexion

of the joint. The radiograms (Fig. 128) are those of a man who, six months previously, was hit by a bullet which perforated the patella from the front. It is interesting to note that the bullet apparently turned on its long axis in the cavity of the joint and entered the inter-condyloid region base foremost, where it remained embedded. A temporary catching of the patella always occurred during flexion of the joint.

The bullet was removed by operation and full function ensued.

The larger subject of gunshot and shell wounds of the knee-joint with accompanying foreign bodies of metal, cloth, or bone will be dealt with under the heading of 'Wounds'.

FIG. 128.

SYNOVIAL FRINGES

Synovial fringes may give rise to the condition that has been known as recurrent traumatic arthritis, and when present produce a definite internal derangement of the knee. They constitute a phase in the development of villous arthritis, and will be fully discussed with that subject, to which they belong ætiologically and pathologically.

DISLOCATION OF THE PATELLA

a. Acute

b. Recurrent.

Acute. Acute dislocation of the patella may be due either to direct violence, laterally applied, or to muscular action. In the latter type the injury is produced by a sudden contraction of the quadriceps, which in other cases might be productive of a transverse fracture of the patella.

The dislocation is as a rule simply a sliding over one or the other condyle, but rarely the patella may be twisted to a right angle so that its surfaces point inwards and outwards.

Reduction of the deformity is simplified by the use of an anæsthetic in order to relax the quadriceps muscle. This should be followed by immobilization in the extended position for at least four weeks in order to enable the torn aponeurosis to heal thoroughly. Immobilization should be combined with massage and faradism to prevent undue wasting of the quadriceps.

Recurrent. Recurrent dislocation is one of the most dramatic derange-

ments of the knee from the standpoint of the patient; it practically always occurs to the outer side. The ætiology of the displacement is suggested by the fact that the line of action of the quadriceps in the axis of the thigh differs from that of the infra-patellar ligament in the axis of the leg. The patella lies at the angle of the meeting of these two axes, so, when the quadriceps contracts, it tends to be pulled outwards as the shortening muscle and ligament become a straight line. There is little doubt that this displacement would be very frequent were it not for the fact that the outer margin of the trochlea surface of the femur acts as the flange of a pulley wheel and so offers resistance to the outward deviation of the patella. It has been pointed out by Goldthwait that in cases of this nature the tubercle of the tibia is displaced too much to the outer side, and in this way there is an additional increase in the angle of the axes of quadriceps muscle and infra-patellar ligament. The condition is very often associated with varying degrees of knock-knee which still further increases the axial angle before mentioned.

The lateral movement of the patella is found to be distinctly increased, and the lateral patella ligaments become so stretched that it is often possible, in old-standing cases, to dislocate the patella by pushing it over the trochlea with one's thumb.

Symptoms are obvious and fairly constant. The patient, for example, on getting up from a chair, feels an excruciating pain in the knee and falls. He is unable to move and the limb is found to be flexed, the patella being on the outer side of the joint. Effusion into the joint follows. In old-standing cases no pain accompanies the displacement and no fluid is secreted.

Reduction is easily accomplished. The leg is extended, the inner edge of the patella elevated and pushed back into place. A gunner, who was sent back from France on account of recurrent dislocation of both patellæ outwards, was treated by means of the operation which was devised by Goldthwait. There was no definite knock-knee, and so preliminary femoral osteotomy was not required. The infra-patellar tendon and lateral patellar ligament were exposed by means of a **J**-shaped incision, the long limb being on the inner side. The tendon was split vertically and the outer half detached from its insertion. This was now passed behind the remaining portion and was implanted into the antero-internal surface of the tibia, by stitching it to the stripped periosteum and to the expansion of the tendon of the sartorius. In addition an ellipse was removed from the lateral patellar ligament and capsule on the inner side and the cut edges of each were sutured to correct the overstretching. After four weeks' immobilization, combined with massage and faradism, a course of gymnastics completed the cure and the man was returned to full duty.

It is interesting to note that Hugh Owen Thomas sometimes treated

this condition by means of continued percussion of the femoral trochlea, applied with a wooden hammer. Chronic pereostitis and osteitis were induced, with the result that a ridge of bone was formed which so increased the flange of the pulley that dislocation was prevented.

CRUCIAL LIGAMENT INJURIES AND FRACTURES OF SPINE OF TIBIA

These conditions are described under one heading as they are so intimately connected clinically. The same type of injury may produce the lesion separately or collectively. Rupture of the anterior crucial may involve its tibial attachment to the internal tubercle of the spine of the tibia. A rupture or stretching of one or both of the crucial ligaments may occur, and commonly does occur, without any damage to the spine of the tibia, and sometimes a portion of the spine may be fractured without any apparent damage to the crucials.

On the upper surface of the tibia the two articular facets turn upwards towards each other in the middle of the joint to form the two tubercles of the spine of the tibia. Along the summit of the spine a groove runs in an antero-posterior direction between the two tubercles and opens out anteriorly and posteriorly in the **V**-shaped intercondylic fossæ. Of the two tubercles, the inner is usually higher and longer antero-posteriorly than the outer one, although the latter is more sharply pointed (Fig. 129). Anatomical variations, however, are found, seen in the radiograms of healthy knees. In the hypertrophic type of rheumatoid arthritis, the tubercles become more pointed than normal. In several radiograms of this condition an exostosis has been noticed growing from the tibia in front of the spine. The anterior crucial ligament is attached to the front of the internal tubercle of the spine and the posterior horn of the external semilunar cartilage is attached to its outer side. The anterior horn of the external semilunar cartilage is attached to the front of the external tubercle of the spine, but apart from this, the latter eminence is free from all ligamentous attachment. In fractures of the spine of the tibia, one must be always prepared for symptoms of injury to the two soft structures mentioned. In 1888 Sir Rickman Godlee described a lesion which he had found years before in a leg amputated by Erichson in 1873. He stated that there had been several injuries caused by the passage of a cartwheel over the leg; amputation was performed fourteen days later. On opening the knee-joint subsequently, a loose piece of bone was found separated from the top of the tibia with the anterior crucial ligament and the external semilunar cartilage attached to it.

The following types of case may occur:

1. Rupture of both crucial ligaments.
2. Stretching or rupture of the anterior crucial.

3. Rupture of the anterior crucial with avulsion of the tibial spine or its internal tubercle.

4. Stretching or rupture of the posterior crucial.

5. Fracture of the external tubercle of the spine.

6. Injury to the spine combined with fracture of the tuberosity of the tibia.

FIG. 129.

1. **Rupture of both Crucial Ligaments** is always due to a very severe injury, usually a dislocation of the knee, and is always associated with rupture of other ligaments. After reduction of the dislocation it is found that the joint is quite flail-like, and that the tibia can be manipulated forwards and backwards on the femur, both in flexion and extension, to an alarming extent. Marked hyperextension of the joint is also found to be present.

Treatment should consist of prolonged immobilization, as described in the section dealing with dislocations of the knee. A good functional result is expected by conservative treatment ; for this reason primary suture of the ruptured ligaments is not recommended.

2. **Stretching or Rupture of the Anterior Crucial Ligament** is a commoner injury than one has been led to believe, especially in military surgery. It is found combined with a torn or displaced internal semilunar, except where the injury has been due to a forcible hyperextension of the joint that has stretched the posterior ligament of Winslow and the anterior crucial at the same time. This type of case is rare, but if it is of long standing ' genu recurvatum ' will be present and the tibia can be brought forward on the femur in the hyperextended position. Conversely, the anterior crucial may be gradually stretched in mal-united fractures of both bones of the leg, set with an anterior concavity. Here body weight is thrown behind the centre of the knee-joint, and the anterior crucial with the posterior ligament have undue strain thrown upon them with every step taken. From the surgical standpoint the anterior crucial is more important than the posterior as it is much more liable to be damaged. The posterior crucial almost invariably escapes, except in those severe injuries which are connected with a dislocation of the knee. Since the war began the question of anterior crucial injuries has been forcibly brought to our notice because of the bad knee sprains that result from the hardships of active service. ' Shell bursts ' on the parapet cause men to be partially buried or forcibly thrown off their feet in various ways. ' Shell hole ' cases where men, heavily equipped, fall into muddy holes are also apt to cause more severe knee-joint injuries than ever came off the football field. I wish to draw attention to the importance, from the military standpoint, of the stretched anterior crucial ligament in connexion with injuries to the internal semilunar cartilage, and to emphasize that this is one of the reasons why operations for removal of the internal meniscus have sometimes proved so unsatisfactory in the soldier. Should the forces which ordinarily rupture the cartilage continue to produce further abduction of the knee, the entire strain is borne by the anterior crucial ligament, which becomes in its turn stretched or torn or the internal tubercle of the tibial spine becomes avulsed. It is obvious that the lesion to the anterior crucial ligament is dependent upon the strain to which the knee is exposed. When one examines a knee-joint which has sustained an injury that betokens a damaged internal semilunar cartilage, the examination is not complete without verifying the integrity of the anterior crucial. Where a stretching of the anterior crucial has occurred, rotation outwards of the tibia is always increased after the removal of the internal meniscus ; also a greater range of abduction in the semiflexed position is present than when the internal lateral ligament

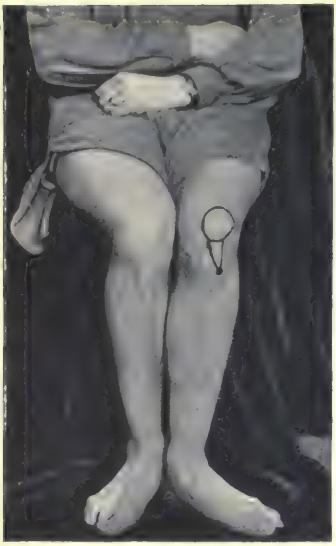

FIG. 130.

FIG. 131.

FIG. 132.

FIG. 133.

alone is ruptured (Figs. 130, 131). Several cases have been seen where the cartilage had been previously removed, and the symptoms of locking relieved, but the weak 'rocking' knee has remained (Figs. 132, 133). On this account the patients have been of the opinion that the laxity of the knee has been due to faulty operation, until the true nature of the injury has been explained to them. It is thus expedient to safeguard oneself by a thorough examination and to verify the structures that are damaged.

When the tibia can be brought forward on the femur in full extension, the anterior crucial is probably ruptured. In old-standing cases of 'rocking' knee, where possibly the internal meniscus has been removed some time previously, I have found at a subsequent operation that the anterior crucial is not fully ruptured, but is stretched and attenuated. From the clinical standpoint the condition is quite as serious as a complete tear, as secondary immobilization, even for a long period, does not appear to strengthen it.


FIG. 134.

The immediate treatment of a stretched or torn anterior crucial should be by immobilization for at least eight weeks; this is considered preferable to primary suture of the ligament. The leg should be kept flexed 20° short of full extension; in this position the ligament is relaxed and no strain can be put upon it. Thereafter an appliance may be used. In the ordinary course, a cage splint of the pattern devised by Howard Marsh will prevent abnormal mobility (Fig. 134). The appliance will be required for an indefinite period of time in those cases where preliminary treatment by immobilization or suture has been unsuccessful. In addition to the cage-splint a crêpe bandage wound round the knee beneath the splint will often give additional security. The foot should be raised, both sole and heel, on the inner side to throw the strain against the external lateral ligament, and to prevent abduction at the knee. The 'rocking' knee, after operation for removal of the internal meniscus, may be dealt with in this way if no further operation be desired. The policy of raising the boot on the inner side is theoretically not quite sound, as a lax anterior crucial ligament allows increased rotation of the tibia, and the alteration to the boot will have the tendency to make the patient walk with his toes turned in. Practically the objection does not hold good, and patients walk with greater security. The use of a cage splint for a stretched or ruptured anterior crucial is fairly satisfactory in the majority of cases,

but a man so fitted cannot be categorized for any service beyond that of a sedentary character. This type of injury can be materially improved by operative means, but this should only be undertaken in cases where, by reason of the man's general military efficiency, it is deemed advisable to do so. Hey Groves has described an operation of fascial substitution, whereby a strip of fascia lata carried through the joint takes the place of the anterior crucial ligament. From the mechanical standpoint I think that the Hey Groves operation is incomplete, in that it does not attempt to strengthen in any way the internal lateral ligament. The new fascial ' ligament ' has to bear the entire strain in both abduction of the knee and anterior sliding of the tibia as well as in internal rotation of the tibia on the femur. I have modified the operation and aim to reconstruct the internal lateral ligament, which is always damaged, as well as to make a new anterior crucial ligament. This operation has been so successful in several cases that I consider repetition of the procedure is justifiable and now perform it as a routine in selected cases.

Operation (*Hey Groves's modification*). The field of operation to be prepared includes the region of the knee and the full length of the thigh. A tourniquet is applied at as high a level as possible on the thigh. The foot-piece of the table is dropped so that the knee lies flexed to 90°. A **J**-shaped incision is made, the long limb is about 16 inches in length and runs vertically down the middle of the outer surface of the thigh. The incision curves transversely inwards and passes across the front of the leg, one inch below the tubercle of the tibia. The short limb is formed by the curving of the incision vertically upwards for about 6 inches on the inner aspect of the knee and thigh. The incision involves the skin and superficial fascia only. The flap is now dissected upwards over the patella, and wound towels are clipped over all the skin edges. The patella is split vertically by means of a fine-bladed saw; the supra- and infra-patellar ligaments are divided in the same line sufficiently to produce wide separation of the two halves of the patella. Strong retraction is required to gain adequate access to the joint. The fat pad is divided vertically with the infra-patellar ligament, and the ligamentum mucosum is cut through at a point where it can be reunited at the close of the operation. The synovial membrane investing the anterior crucial is divided and the ligament is examined. The upper level of the supra-patellar pouch is now noted as it is advisable that the fascial strip should pass into the femur slightly above this to avoid any unnecessary intra-articular disturbance. A hole is bored by means of a long drill, with a ¼ inch diameter upwards and outwards through the shaft of the femur from the site of the upper attachment of the anterior crucial ligament, to a point on the external surface slightly above the upper level of the supra-patellar pouch. The

internal tuberosity of the tibia is now drilled from a point slightly anterior to the insertion of the sartorius, upwards, backwards, and slightly outwards, to a point on the superior articular surface of the tibia just anterior to the internal tubercle of the tibial spine. A strip of fascia lata $1\frac{1}{2}$ inches wide is cut on the outer side of the thigh. This strip is attached at its bottom end and should be about 10 inches in length. A long flexible probe, with an eye large enough to take the fascial strip, is now pushed, eye first, through the tibial drill-hole into the knee, upwards through the femoral drill-hole until it emerges on the outer side of the femur. The division of a few fibres of the vastus externus is necessary to bring the probe into view. The free end of the fascial 'ligament' is threaded and the probe is withdrawn, bringing the 'ligament' with it. An antero-posterior channel is now bored through the adductor tubercle with a large-sized shoemaker's awl, which makes a channel curved in a postero-internal direction. This is necessary to avoid damage to structures in the popliteal space. The free end of the fascial strip is now threaded through this channel from back to front. The foot-piece of the table is raised so that the knee lies in a position of 20° of flexion. The tibia is forced backwards on the femur. As much tension as is thought fit can be applied to the new ligament, but it must be remembered that when the leg is extended it will automatically tighten still farther. The 'ligament' is pulled tight both in its intra-articular portion and also in that part of its course where it substitutes the internal lateral ligament. It is sutured to the periosteum around the tibial and adductor orifices, and if the length is sufficient the free end is stitched to that portion of the strip which lies just below the adductor channel (Fig. 135). Strong chromic catgut should be used. The edges of the strip should be sutured to the subjacent lateral patellar ligament to ensure as perfect co-aptation as possible. The fascial ligament curls on itself as it passes through the bone and makes an anterior crucial substitute which is about the thickness of a slate pencil. As Hey Groves points out, the tension of the attached portion of the strip is

FIG. 135.

from below upwards and consequently strengthens the external lateral ligament.

The two halves of the patella are apposed. The tourniquet is removed and the hæmorrhage checked. The halves of the patella are drawn together by three or four chromic catgut sutures through the aponeurosis; another stitch should co-apt the divided fat pad. A small cigarette drain is placed through the split in the infra-patellar tendon between the two halves of the fat pad and should extend down to but not into the cavity of the joint. Time can be saved by the use of Michels clips for the closure of the long skin incision.

The leg is put on a Thomas's skeleton splint, with foot-piece, in a position of 20° of knee flexion. The cigarette drain is removed in 48 hours. A certain amount of oozing continues until the third day, so the wound should be re-dressed on the fourth day. At the end of a fortnight a plaster of Paris cast can be applied, still with the knee slightly bent. At the end of four weeks massage and faradism to the quadriceps is begun and gentle active movement is permitted. A support should be worn for another fortnight.

Hey Groves has suggested the use of the semi-tendinosus tendon for the replacement of the posterior crucial ligament. This operation is of greater difficulty than the one described above, on account of the inaccessibility of the femoral and tibial attachments of the posterior crucial. On account of the rarity of posterior crucial injuries, it will have a limited field.

3. **Rupture of the Anterior Crucial with Avulsion of the Tibial Spine or its internal Tubercle.** This injury was first described by Hogarth Pringle in 1907. It is produced by violent tension on the crucial ligament, such as is caused by a heavy fall, the knee being in the flexed position and the tibia forcibly abducted and rotated inwards. The deep fibres of the internal lateral ligament are torn in addition. It is interesting to note that in cases of this type of injury which have come before my notice, the superficial fibres of the internal lateral ligament have remained intact. This would lead one to infer that the knee was flexed beyond 20° before the forces of abduction and rotation began to act. X-ray will show the fracture of the whole spine or its inner tubercle.

In cases of old standing it is not uncommon to find that a displaced cartilage has been diagnosed and even operated upon, the true condition having remained undetected. All cases of a few weeks' standing display inability to fully extend the joint. It is essential that all cases which display inability to fully extend the joint should be radiographed, although the 'bone' block of a tibial spine case should readily be diagnosed from the 'elastic' block of a displaced internal meniscus.

In recent cases of avulsion of the tibial spine, despite the advice of

Hogarth Pringle, I think it is advisable to try the effect of immobilization of the knee, in the extended position, for about ten weeks, rather than treatment by primary operation and fixation of the bony insertion of the ligament. Massage and faradism to the quadriceps with passive movements of the patella should be carried on at the same time.

In cases of old standing, however, operative measures are indicated purely on account of the inability to fully extend the joint. Abnormal mobility in abduction, anterior sliding, and internal rotation are noticeable in recent cases only. After five or six weeks the structures appear to tighten up to such an extent that limitation of extension is the only disability. Treatment is exemplified in the following case :

Lieutenant F., admitted to Orthopædic Centre with a history of having fallen into a 'shell hole' with the affected leg flexed beneath him, six months previously. Extreme pain was experienced in the knee immediately—the joint became fixed and marked effusion was present. A back splint was applied at the base hospital, but the leg did not fully extend. The internal meniscus was removed a month later in a military hospital in this country. The result of the operation was unsatisfactory, as the limitation of movement was not improved thereby. After five months' electro-massage he was admitted to an orthopædic centre. Thirty degrees of active movement were present. Full extension was limited by over 20°, the obstruction appearing osseous rather than fibrous. No anterior crucial laxity could be elicited. X-ray showed fracture of the inner tubercle of the tibial spine with new bone formation.

Operation.—Joint exposed by split patellar route. Excess bone on the anterior part of the tibial spine was chiselled away. The anterior crucial was found to be fully separated from the tibia, but had a small fragment of bone remaining attached to it. The ligament was held in position by its synovial covering, but a few of its most external fibres were found to be attached to the anterior horn of the external semilunar cartilage. The ligament was embedded in the raw area of bone that remained after the excess callus was removed and stitched by catgut sutures to the anterior horn of the external meniscus and to the transverse ligament. The knee was found to extend fully, and after the wound was closed in the usual manner the whole lower extremity was immobilized for ten weeks.

4. **Stretching or Rupture of the Posterior Crucial.** Rupture of the posterior crucial ligament alone is very rare. On two occasions I have diagnosed a stretched posterior crucial in conjunction with a sprained external lateral ligament. Doubtless the stretching of the crucial was a secondary manifestation dependent upon faulty mechanism. In such cases the tibia may be forced backwards on the femur in the fully flexed position of the knee. They should be treated by immobilization of the

joint combined by massage, followed by the use of a cage splint to prevent adduction of the knee. Mechanical assistance will be obtained by the raising of the sole and heel of the boot on the outer side to throw body weight on the inner side of the knee.

5. **Fracture of the External Tubercle of the Spine.** This fracture is not connected with injury to the crucial ligament. The fragment of bone broken off may be small and is not in the region to which either of the ligaments is attached. The top of the external tubercle is shorn off from behind by the inner sharp margin of the external condyle, either by the femur being driven towards or the tibia being driven backwards (Fig. 136).

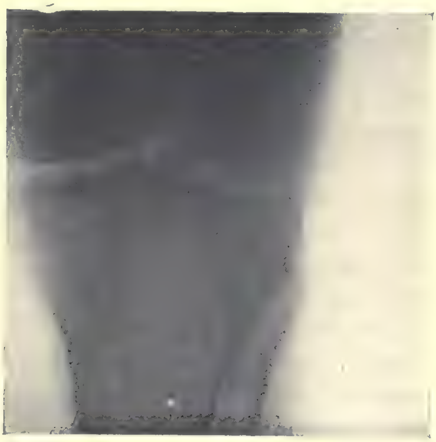

FIG. 136.

The height of this tubercle varies in different subjects, and apparently it is the high type of spine that is liable to suffer this injury. Experiments made by the writer show that after division of the internal lateral ligament, with rotation outwards of the tibia on the femur and abduction at the knee, the femur can be forced forwards, and the inner sharp margin of the external condyle can be made to impinge on the outer tubercle of the spine and fracture it. Similar mechanism to that which produces a torn or stretched anterior crucial will produce this injury, with the exception that the tibia in this case is rotated outwards instead of inwards. The injury is commonly caused by the soldier being thrown on to the flexed knees with the feet turned outwards in the moment of falling forwards on to his face ; superincumbent body weight ruptures the internal lateral ligament by torsion and the femur is forced forwards on to the tibia. It is probable that the fracture of the spine takes the strain off the posterior crucial ligament, which might readily be damaged otherwise by a fall of this nature. The internal semilunar cartilage may be damaged at the moment that the internal lateral ligament is ruptured, by reason of the outward rotation of the tibia on the femur. A large amount of effusion into the joint follows, and the condition is generally diagnosed as a damaged internal semilunar cartilage, on account of inability to fully extend the joint. This diagnosis may be correct in part, as the semilunar may be involved. The X-ray will show that a mass of bone has been forced into the front of the joint and is acting as a block to full extension. The limb should be manipulated as for the reduction of an internal semilunar cartilage, to obviate the likelihood of a dual

injury. By manipulation in rotation and extension the bone can easily be forced backwards until the joint is capable of full extension. When this is obtained, the limb should be immobilized in the fully extended position and kept so for five to six weeks ; this immobilization should be combined with massage and faradism to the quadriceps. Gentle active movements may then be permitted and a good functional result should follow. Cases of old standing that have not been satisfactorily treated will display a definite bony block which prevents extension of the joint. These cases should be treated by operation. The knee should be opened by the split patellar route, the hypertrophied fat pad which is constantly found on account of the trauma should be removed, and the bony mass should be chipped away by means of a fine chisel. A full inspection of the semilunar cartilages should be made, and the internal meniscus removed if necessary.

6. **Injury to the Spine combined with Fracture of a Tuberosity of the Tibia.** This is a rare injury and is a more severe lesion than others described above. The external tubercle of the spine may be fractured with the internal tuberosity of the tibia, or avulsion of the inner tubercle of the spine may be combined with a fracture of the outer tuberosity of the tibia. Injury to the tuberosity is always of the nature of a crush fracture, and would appear to be due to a more direct type of injury causing forcible abduction or adduction of the knee, as the case may be. The treatment should be as above, with the exception that the knee-joint should be immobilized in the fully extended position for a longer time. The reason of this is obvious, as in an untreated case on which I was called to operate six months after the injury the fracture of the tibia was such that a large shelf of bone involving the front half of the inner tuberosity remained after the fractured outer tubercle of the spine had been chiselled away ; this prevented extension of the joint and nullified the result of the operation. Such cases often display a marked lateral mobility of the knee-joint on account of the downward displacement of the fractured tuberosity. A cage splint will probably be required for an indefinite period, and the injury must be regarded as one of extreme gravity.

DISLOCATION OF THE KNEE

Dislocation of the knee is, fortunately, a rare accident, and is always produced by extreme violence. There are three varieties, which, in order of frequency, are as follows :

1. Forward dislocation of the tibia.
2. Backward dislocation of the tibia.
3. Lateral displacement.

1. **Forward Dislocation of the Tibia.** The forward displacement is

caused by violent hyperextension of the joint. The posterior ligament of Winslow, the crucial and lateral ligaments are ruptured and the tibia lies in front of the femoral condyles. I have seen this injury as the result of the leg being caught in the spokes of the revolving wheel of a gun limber.

2. **Backward Dislocation of the Tibia.** Posterior dislocation is caused by violence, which is applied either to the front of the leg or the back of the thigh. The upper end of the tibia occupies the popliteal space. This type of injury is often complicated by paralysis of the popliteal nerves due to pressure.

3. **Lateral Displacement.** Lateral dislocation may be complicated by fracture of one of the tuberosities of the tibia.

A diagnosis in either case is usually made, although there is very marked swelling as the result of tearing of blood-vessels. The reduction is easily obtained by extension and manipulation.

In (2) there may be some difficulty; if so the leg should be fully flexed and forward traction on the head of the tibia applied before the leg is extended.

The interesting feature of these injuries is the fact that the crucial and lateral ligaments are always torn, and that popliteal paralysis may be expected. Treatment should always be conservative. Good results have been obtained by several observers with prolonged immobilization of the knee in the extended position. The limb should be absolutely immobilized by appliance or plaster of Paris for at least twelve weeks. Primary suture of the crucial ligaments is not to be recommended on account of the difficulty of getting end-to-end apposition, as in all probability the ligaments have ruptured near their bony attachments. Torn structures must be given time to unite firmly, and after ten weeks' immobilization combined with massage and faradism to the quadriceps muscle, graduated exercises should begin. As a general rule, considerable freedom of movement is recovered and a useful limb results. Should the results of this treatment be unsatisfactory, a second operation can, if necessary, be performed by the substitution of a fascial ligament, as is described in the section dealing with rupture of the crucial ligaments.

ARTHRITIS

Arthritis in the knee-joint may be either traumatic or hæmatogenous in origin; sometimes both these causes may be traced as ætiological factors. It is definitely known that the irritation caused by persistently recurrent displacement of a semilunar cartilage or loose body is liable to cause hypertrophic rheumatoid arthritis or even tuberculous changes in the joint.

Villous Arthritis. It has been decided to group all cases of synovial fringes and joint lipomata under the heading of villous arthritis, as there can be no doubt that all such cases are allied to one another and are merely degrees of one and the same condition, which is that of reaction of the joint to small but recurrent injuries. The infra-patellar pad of fat fills the triangular space between the patella in front and the femur and tibia behind. The synovial membrane is reflected over this fat pad and a triangular fold passes upwards and backwards to be attached by its apex to the anterior extremity of the intercondyloid notch. This fold is called the ligamentum mucosum. The free margins of this fold diverge and enclose the lateral confines of the fat pad. The lateral free edges of the synovial covering are irregular in outline, caused by protrusions of the imprisoned fat. These lateral free edges are known as the alar ligaments. When the knee-joint is extended and the patella is elevated by means of a well contracting quadriceps, the fat pad becomes flattened in an antero-posterior direction and the alar ligaments are pulled from the neighbourhood of the joint surfaces. If, however, an undue accumulation of fat is present in the fat pad or the quadriceps loses its tone for any reason, the alar ligaments with their contained fat may become ' nipped ' between the femur and tibia in extension of the joint. The condition is often associated with flat foot. It is probable that ' nipping ' of the alar ligaments occurs in conjunction with flat feet, on account of faulty mechanism in rotation of the tibia during extension of the knee. When a small portion of one of the alar ligaments is ' pinched ', a hæmorrhage will take place as the fat that is enclosed is supplied with a small blood-vessel which will probably be ruptured. The fringe will be enlarged and its outline will become more serrated; in addition the investing synovial membrane will be damaged, and a localized effusion into the joint will result. Swelling will take place, due to the following causes :

1. Free effusion into the joint which is not well marked.
2. Swelling in the fat pad due to ecchymosis.

The fat pad becomes much enlarged and the free edges become irregular in shape and small tongue-like projections are formed which are called ' villi '. On account of the enlargement in the size of the fat pad, the projections of the alar ligaments will become more liable to temporary ' nipping ' between the articular ends of the bone in full extension.

Synovial Fringes. Where the condition is not well marked and where only a few synovial fringes have manifested themselves in or around the alar ligaments, the condition is one described as synovial fringes, and will require to be diagnosed from injuries to semilunar cartilages and loose bodies. A large fringe formed by a hernial protrusion of fat into

a portion of the synovial membrane is called a ' lipoma arborescens ', but this is not of importance from the standpoint of differential diagnosis. There is a type of young and athletic man in which the fat pads appear to be unduly large. The infra-patellar fat pad may be unduly large in the case of very stout people, where the thickening is due to the same

FIG. 137.

cause as the general lipomatous condition. In this type the intra-articular lipomatosis will decrease whenever there is a diminution of the general subcutaneous adiposity. The X-ray of a fat pad that has suffered several injuries shows definite fibrous masses in the plate (Fig. 137). The shadows, as seen in the X-ray, are due to fibroid changes taking place in the core of the fringes following upon hæmorrhage into them. The signs and symptoms displayed by a case of ' nipped ' synovial fringes are different from those in a damaged cartilage case. There may be

a sudden catch in the joint which immediately passes off, but apart from this, as a rule no derangement is noted. Effusion may occur, but not to the same extent as in cartilage injuries. Pain and effusion are apt to come on after exercise has been taken, but without any definite knowledge that any mechanical indiscretion has occurred. At no time on examination is it found that there is pain complained of on palpation over the lateral ligaments of the joint, nor is there any tenderness over the articular margin of the tibia at the site of the anterior horn of the internal semilunar cartilage, both signs being definitely suggestive of damage to the semilunar cartilage. The infra-patellar fat pad will be found to be swollen; this is definitely shown by the marked thickening on either side of the patella. Pain will be complained of walking downstairs, and the patient, as a rule, will state that he has weakness of the quadriceps muscle. A fine rub may be felt on palpation, and if the fat pad be compressed during flexion and the leg be forcibly extended, pain and discomfort will be felt on either side of the patella. It is obvious that the longer the offending fringes become, the more will the symptoms of derangement of the knee dominate those of synovial irritation.

There can be no doubt that recurrent trauma in the joint is responsible for the condition of synovial fringes and villous arthritis, the latter being a more advanced stage of tissue reaction than the former. It is also certain that these cases pass on to the hypertrophic type of rheumatoid arthritis if the irritative factor be not removed. I am not satisfied that the cause is always due to trauma alone, as many cases have come before me where some chronic infection has been present elsewhere in the body which was thought to have kept up the irritation.

A British officer seconded for duty with the Canadian Forces consulted me in 1912 with definite symptoms of synovial fringes which had been causing him trouble for the previous two years. He stated that the condition was not a disabling one, provided that he was walking or riding on the prairie, but that walking up and down steps or on hard pavements produced pain and effusion. There was a history of chronic constipation which was always better when living in training camps in the open. A year afterwards I removed large synovial fringes from both sides of the joint, all from the region of the fat pad. Convalescence was uneventful, but recovery was not as complete as one would have expected. Two months after operation, abdominal symptoms of a chronic nature arose, and the officer was granted sick leave to return to England. A chronically inflamed appendix was removed, and apart from the improvement in his general condition, all symptoms in the knee-joint quickly cleared up. In due course the knee became as strong as the other and withstood active service conditions for three months, after which time the officer was unfortunately killed in action.

Rheumatoid Arthritis. Rheumatoid arthritis, as it affects the knee-joint, may be

(*a*) Hypertrophic ;
(*b*) Atrophic.

(*a*) **Hypertrophic Rheumatoid Arthritis.** The hypertrophic type, as suggested above, is the result of trauma, and is very often the sequel of villous arthritis. This type of arthritis may be due to either the irritation produced by recurrent injuries to a semilunar cartilage, or to that produced by synovial fringes and fat pads. The condition is liable to be monarticular, and it differs from villous arthritis in that bony changes take place as the result of tissue reaction in the joint, whereby, as the result of continued irritation, cells of a high degree of differentiation are substituted by repair cells of a lower type. Considerable ' lipping ' is shown in the X-ray pictures, always evident at the articular edges of the joint ; it is also seen along the edges of the patella. The majority of the bone proliferation takes place at chondro-osteal junctions. Should the irritation be continued, further changes in the articular cartilage are bound to develop. Cartilage cells become disorganized and are not replaced, subjacent bone cells proliferate, and where they are not kept down by constant friction overgrowth occurs. Where constant friction between the bone surfaces takes place, all the cartilage cells disappear, and hard eburnated bony surfaces are found in contact with one another.

Clinically there is limitation of movement, some effusion in the joint, and a fullness around the patella, is manifested ; a coarse ' creak ' on palpation is felt on movement beneath the examining hand. Any attempt to fully extend the joint is painful. This type of arthritis is fairly common in soldiers, and may be expected in men very much younger than one is accustomed to find it in peace time. Long-continued route marches with a heavy pack on an over-tired man, who may or may not have a tendency to flat foot, is apt to develop or mature a hypertrophic rheumatoid knee. All men who complain of an aching pain in one or both of their knees after marching, and who display a thickened infra-patellar fat pad, should be X-rayed as a routine. If circumferential ' lipping ' of the patella is to be seen accompanied by bone changes around the articular margins of the femur and tibia, the condition is obvious, and must be treated by limitation of movement, and subsequent classification in a lower category. Many cases with this condition have been returned from France with a diagnosis of an internal derangement, and operated upon in this country for displaced cartilage or synovial fringe. From the military standpoint no operation is indicated ; in fact any operative interference is to be strongly condemned, unless very definite symptoms

of recurring derangement exist. If the latter are present, operation is indicated, not to cure the condition, but merely to prevent further irritation in the joint. Where bone changes have taken place, it is useless to expect a return to normal by any treatment, but the prevention of painful movement, both in flexion and extension, will bring about marked improvement in the condition and will enable the patient to be retained in the service for duty in garrison or labour battalions. Movement, as a rule, is painless between a range of movement from 160° to 90° flexion, beyond 90° is apt to cause pain. Forcible extension of the joint is invariably accompanied by pain.

Treatment should consist in the use of a Marsh knee-cage, which only allows movement within the painless range, and is so locked as to prevent any strain being put on the joint in full extension or full flexion. A course of radiant heat to the joint and faradism to the quadriceps is beneficial. It is essential to remember that undue friction of joint surfaces is a factor to be scrupulously avoided, and any treatment which ignores this is faulty. After a month or so of treatment by restricted movement, pain becomes very much less, and increase in the range of painless motion is found ; this is due to the atrophy of the thickened villous synovial membrane that occurs when it is not subjected to irritation. The appliance can be altered from time to time to allow additional degrees of movement.

(*b*) **Atrophic Rheumatoid Arthritis.** Atrophic rheumatoid arthritis is always multi-articular, and is generally due to septic disturbances in the gastro-intestinal or genito-urinary tract. The primary focus may be found in septic tonsils, a chronically inflamed appendix or an old-standing prostatic infection. This condition is not common in the soldier, and rarely comes within the scope of military orthopædics. Treatment should conform to the lines laid down for other forms of arthritis which produce ankylosis.

Septic Arthritis. Septic arthritis of the knee-joint in the soldier is generally due to gunshot or shell wounds of the knee, and is dealt with under ' Wounds ' (q. v.).

Gonococcal Arthritis. Arthritic complications of gonorrhea, when they occur, tend to affect the larger joints. The condition may attack the knee as a metastasis, occurring about three weeks after the initial infection, if local treatment has been deficient. This complication is not a common one in the army, but when it occurs it should be treated with the care that its severity demands. The arthritis affects the entire joint surfaces, and a dry erosion of the cartilage is apt to occur, producing limitation in movement.

Treatment by rest to the joint in the position of full extension with the foot at a right angle is required, radiant heat can be added after the

acute symptoms have subsided. Ankylosis or limitation of movement in varying degrees may result.

Tuberculous Arthritis. Tuberculous arthritis, when it does occur, will probably be coincidental to military service, although the pensions warrant assumes that all such cases are exaggerated by military service if it develops during service. Two types may occur, the commoner osteal type in which there is a thickened spindle-shaped joint, with all contours obliterated and the synovial membrane is obviously thickened. Limitation of movement will be the first symptom to be looked for, the joint cannot be fully extended or fully flexed. Pain may be absent or there may be a dull aching pain after exercise. The condition will require to be diagnosed from hypertrophic rheumatoid arthritis, but this should not cause any difficulty, as in the tubercular joint a thickening of all joint structures is manifested, and the capsule of the joint feels gelatinous to the touch. The rarer type of synovial tubercle is more benign in its course, and will require to be diagnosed from villous arthritis. There is a marked thickening of the supra-patellar pouch in this type of case, which is known as hydrops articuli. Tuberculous arthritis of the knee-joint is not often met with in military orthopædic hospitals. The treatment must aim at rigid immobilization for a prolonged period. It is a matter for decision as to whether the joint fixation should be by operative or mechanical means. Where the articular surfaces are diseased, ankylosis is the best result that can be looked for in the adult type of case. It is usually advisable to perform an excision of the joint, removing as much of the diseased tissue as is possible at the operation. Should the case be one of long standing where sinus formation and secondary infection have occurred the severity of the case will be intensified, and treatment by prolonged immobilization in the open air or by amputation must be decided.

DIFFERENTIAL DIAGNOSIS OF INTERNAL DERANGEMENTS

(*a*) **Injury of the Internal Semilunar Cartilage** is diagnosed by the acuteness of the onset, by a persistence of pain on pressure over the detached or injured area and by locking of the joint. The patient usually refers the pain to the front of the joint until one carefully palpates the joint margins, here one obtains a definite painful spot over the articular edge of the tibia at a mid-point between the inner border of the infra-patellar tendon and the anterior edge of the internal lateral ligament. In addition, in recent cases, there may be pain over the internal lateral ligament itself on account of the injury that often takes place to this ligament when a cartilage is first displaced or torn. Irregularity is sometimes felt on palpation around the articular margin, and often

a sense of discomfort is complained of when the tibia is abducted and rotated outwards. This same symptom is obtained when one gives a light blow sideways to the inner side of the foot. The history of the mode of production is helpful in diagnosis.

(*b*) **Injury to the External Semilunar Cartilage** may give a corresponding train of symptoms which will be referred to the outer side of the joint.

(*c*) **Synovial Fringes.** The symptoms of the ' nipping ' of the synovial fringe are less acute in the first instance than are those of displaced cartilage. The pain is practically localized to the fat pad, and is not referable to the internal lateral ligament, unless there is co-existing flat foot, in which case there may be a slight strain of the superficial fibres of the internal lateral ligament. Pain on palpation is always felt on either side of the infra-patellar tendon, and on pressing both sides of the fat pad together, a shooting pain is sometimes complained of running across the knee. Frequently a prominence may be found over the site of pain, and, no matter how often the ' nipping ' occurs, a certain amount of effusion follows. A creaking in the joint is frequently present, usually elicited by laying the examining hand over the patella, asking the patient to extend and flex the joint. An obvious swelling occurs on either side of the ligamentum patellæ, due to the chronic thickening of the infra-patellar pad.

(*d*) **Lipomata.** Lipomata, which are merely hernia-like protrusions of fat into the synovial membrane, may give the same symptoms as synovial fringes ; exercise rather than accident produce the symptoms, which are rarely acute.

(*e*) **Loose Bodies.** Single loose bodies, when pedunculated, cannot as a general rule be diagnosed from cartilage injuries except by X-rays. Loose bodies, as a rule, can be found and located by the patient ; they lock the knee, but only in a transitory manner. The symptoms are sharp but not acute, and unless pedunculated they may be referred to different places within the joint. Effusions are commonly associated with the lockings that occur.

(*f*) **Osteomata.** Osteomata can be found by manipulation and by radiography ; they sometimes lock the joint when a muscle or tendon becomes entangled.

(*g*) **Rupture of the Crucial Ligaments.** Rupture of the crucial ligaments is the accompaniment of so severe an injury that other structures participate in the general strain. Preternatural movement in an antero-posterior direction is present and when the knee is flexed lateral movements are free. If the lateral ligaments are torn, lateral movements in the extended position are also free.

(*h*) **Fractures of the Spine of the Tibia.** Fractures of the spine of the

tibia may complicate (*g*), here there will probably be inability to fully extend the joint owing to a fractured piece of bone blocking full extension. Radiography will be required to verify the diagnosis.

WOUNDS

Wounds may be caused by either rifle bullet or shell fragment, which invades the articulation with or without bony damage.

At the beginning of the war a perforating knee wound caused by an undistorted bullet was the only type where one could predict cure with probable function.

The primary operative treatment of knee-joint wounds in Casualty Clearing Stations and Base Hospitals, as inaugurated by Colonel Gray, has revolutionized the entire outlook, and many knee-joints are now saved where, three years ago, ankylosis or amputation would have been the outcome.

Types of wound are classified by Gray as follows—together with the primary treatment that is advised by him:

Class 1. (*a*) Cases of effusion without lodgement of the projectile in the joint where it is doubtful whether the synovial cavity has been traversed or the synovial membrane has been merely bruised.

(*b*) Those where the synovial cavity has been traversed by a clean rifle bullet without injury to the bones.

(*c*) Those in which the bullet has cleanly perforated one of the bones, entering into the articulation.

Effusion into an intact knee-joint in association with a fracture of the femur must be borne in mind.

Cases belonging to Class 1 should be treated by expectant methods. Should any suspicion as to infection arise, the joint should be aspirated and the sanguinous or synovial fluid examined bacteriologically. If organisms are found it is advisable to immediately open the joint and thoroughly irrigate with some warm non-irritating antiseptic. The joint should be closed and a drain inserted, which should be removed after twenty-four hours.

Where there is a small wound and where there is only slight damage to bone or soft tissues, hæmarthrosis may occur. If effusion cannot be aspirated owing to clotting having taken place, it is advisable to open the joint by free incision on one or both sides of the patella. The clot should be washed out with sterile saline or flavine solution, and the wound should be sutured. If the original wounds are very small they will only require superficial sterilization, unless they come in the line of the fresh incisions, when they should be completely excised. A big blood clot in the joint forms excellent pabulum for the growth of organisms, and even

if it does not become infected, it is often the cause of firm intra-articular adhesions at a later date which complicate after treatment.

Fixation of the joint is a *sine qua non* in all cases of this class until they arrive in England. A Thomas bed-splint with a foot-piece answers the purpose admirably.

When such a case appears in an Orthopædic Centre, voluntary movement is generally present, but the extremes of flexion and extension are lost. Adhesions with a traumatic villous arthritis of varying severity are the usual complications. Treatment by radiant heat, massage, and graduated movement should begin as soon as possible, and in time almost full recovery should take place.

Should there be a ' creaking ' on palpation of the joint and complaint of pain in the extremes of movement, painful motion must be prevented by the temporary use of a cage-splint, which limits full flexion and extension. Vide Villous Arthritis.

Class 2. (*a*) Cases in which the projectile has lodged within the synovial cavity.

(*b*) Those in which it has lodged in one of the articular ends.

In (*a*) when an undistorted rifle bullet lies within the joint, if the superficial wound is small and not inflamed, operation may be deferred for a few days, but it is safer to remove it at once. Free fragments of shells, bombs, or distorted rifle bullets must be removed at once.

In (*b*) clean rifle bullets so situated as to not interfere with the movements of the joint need not be interfered with at an early stage, and sometimes may be left indefinitely.

Other missiles that have probably introduced infective material must be promptly removed. A localizing radiogram is required. It is advisable to remove the body by the shortest and safest route, but as the original wound is infected and will require excision, no advantage except that of direct access is gained by a special incision. The incision for the removal of infected bodies should be free, as the extraction is often difficult. The bone surrounding the fragment must be removed. It should be cut away by a sharp chisel, and should not be merely scraped with a curette. The wound can be sutured at once, but it is probably safer to leave the wound open for a few days, treating it with a paraffin paste dressing or Carrel's irrigation method. The former method appears to be less irritating and to give equally good results.

Class 3. (*a*) Cases in which the synovial cavity has been widely opened with damage to articular surfaces.

(*b*) Cases with fissured fracture or slight comminution of the articular ends.

This class of case requires treatment by primary excision of the

infected part, and good results with mobility of the joint may be expected if operated upon within twenty-four hours.

Class 4. (*a*) Cases in which serious comminution of one or more of the constituent bones exists.

Fig. 138.

Extensive comminution of the cancellous tissue of the head of the tibia or the condyles of the femur may prove very dangerous, owing to the severe constitutional disturbances which follow septic absorption from the injured spongy bone.

In favourable cases, taken early, the chiselling away of infected bone followed by salt pack or Carrel's dressing may be tried, but the majority require amputation.

Class 5. **Fractures of Patella.**

(*a*) Clean fractures produced by the direct passage of a bullet.

(*b*) Simple transverse fracture caused by sudden muscular contraction of the quadriceps following bullet wound in the thigh.

These cases should be treated by conservative means, and cure with function of the joint should be obtained (Fig. 138).

(*c*) Comminuted fractures. Cases of this type are often seen where the whole bone is involved.

Early radical treatment by removal of the entire bone is required. The hole thus made can be safely closed in early cases by suture of the synovial membrane which may require to be undercut to obtain apposition without tension. An attempt is thus made to procure a movable joint.

If infection has begun free drainage will be necessary.

The after-treatment in Orthopædic Centres of primary patellar excisions depends upon the amount of scar tissue that remains. Some cases exhibit a complete fibrous ankylosis, owing to the spread of infection into the anterior compartment of the joint, and a permanent stiff knee may result.

Treatment must be on general lines as laid down for fibrous ankylosis, and in some cases, when movement has been obtained, little disability remains. The leg in the latter instance may be weak and tend to give way in walking up or down stairs. A cage-splint allowing 45° to 60° of movement should be worn as a safeguard.

Primary Excision of Wounds of the Knee-joint. The ultimate object is to secure mobility of the joint, so the primary object at the Casualty Clearing Station must be to secure asepsis. It is essential to excise completely, if possible *en masse,* all tissue which is definitely or probably infected.

Colonel Gray lays down the following operative principles :

(1) Excision of the wound is best performed with the knee held in the same position as when injured, otherwise the track of the missile may be distorted.

(2) Thorough disinfection of the skin and track. The external wound and track may be disinfected, if small, by the actual cautery ; if large, by rubbing in 10 per cent. picric acid in spirit. This has the effect of drying the tissues.

(3) Careful and complete excision of the external wound and track, including the edges of the wound in synovial membrane, in one piece if possible. Incision by means of a sharp scalpel must be made quite clear of the deep as well as the superficial wound. Pockets should not be cut into, and the piecemeal clipping of infected material by scissors is to be condemned.

(4) Ample access to foreign bodies and comminuted surfaces of the joint is necessary, as any groping with the finger is apt to push the missile or infective material out of reach. Incisions must therefore be free and chosen to give the easiest access.

(5) Careful removal under direct vision, if possible, of all foreign material whether free in the joint or embedded in the articular surfaces. If the latter, the bone surrounding the foreign body must be gouged away *en masse*. The joint cavity is flushed with saline or flavine solution. Bone cavities may be wiped with bipp.

(6) The wound should be closed in layers, using fine catgut for the synovial membrane. Drainage tubing should go 'down to' but not project into the joint, unless the Carrel-Dakin method for the introduction of fluid be used. Here the tubes should be carried to the deepest recesses of the joint, but they should be removed as soon as possible.

(7) If the wound in the synovial membrane cannot be closed, a small salt pack independent of the dressings should be inserted firmly 'down to but not into' the joint. This should be left in position until it is quite loose, otherwise protective adhesions shutting off the main cavity of the joint may be broken down and infection occur.

(8) Tendinous or ligamentous structures exposed during operation should be covered by skin or subcutaneous tissue to obviate their subsequent sloughing.

(9) Effusion must be prevented by drainage, which must not invade the synovial cavity. Tension must be avoided at all costs, because it interferes with healthy circulation in, and absorption by, the synovial membrane, and these are essential in combating successfully any infection which may have been overlooked.

(10) The limb must be suspended in the position that is most favourable for drainage.

(11) The injection of irritant antiseptics into closed joints is not recommended.

(12) Localizing radiograms, prior to operation, are essential.

Remote Results. The excellent primary results of immediate operative treatment to wounds of the knee-joint must not blind us to the fact that such joints are not always clinically sound.

The end results of many of these cases, where the joint *per se* has been saved, are not good on account of the loss of bone that it was necessary to remove at the primary operation.

Complications of Wounds of the Knee-joint.

(1) Injury to popliteal nerves.

(2) Ankylosis.

(3) False joint.

(1) *Nerve Injuries.* Both popliteal nerves may be injured, but as a rule the external alone appears to suffer in knee-joint wounds. Where this complication exists, preparatory treatment for the injured nerve by posture and electricity must be carried on simultaneously with the treatment of the knee-joint condition, until the latter wound is healed. Nerve suture should not be undertaken until wounds have been healed for three months, unless the latter healed naturally or operatively by primary union. It may be necessary to flex the knee in order to gain end-to-end apposition of the divided nerve. Should it be assumed that function with movement of the joint will not be obtained, it is necessary to operate on the nerve condition in the first place. If flexion of the knee is necessary for the nerve suture, the flexed position should be maintained for at least six weeks. Should ankylosis be present preventing gradual extension of the leg, an arthrodesis of the joint should be subsequently performed. On several occasions, where there has been no marked shortening of the severed nerve, I have been able to combine arthrodesis with the nerve suture.

(2) **Ankylosis** may be real or apparent. The former may be :

(*a*) Fibrous ;
(*b*) Bony.

Either type may be due to patellar-femoral or tibio-femoral fixation, or both.

Apparent ankylosis may be :

(*c*) Psychopathic ;
(*d*) Secondary to injury of muscles acting on the joint.

(*a*) **Fibrous Ankylosis** is the result of repair tissue extending between the bones of the articulation. It is commonly seen in the latter stages of treatment in military surgery as the result of wound infection, but may occur as the result of other types of arthritis. The joint fixation may be absolute or there may be a few degrees of active and passive movement present.

It cannot be impressed too strongly that the most conservative treatment is required in this condition, and any forcible manipulative surgery may be followed by disaster. As the result of irritation the condition may become fibro-osseous or even osseous.

(*b*) **Bony Ankylosis** is the result of a graver injury to the joint surfaces than occurs in the former type. More cartilage is lost or destroyed, and the scaffolding that is formed between the bones during repair becomes osseous by the laying down of bone cells, so that a synostosis results.

(*c*) **Psychopathic Ankylosis** may often occur as the result of superficial wounds of the thigh or in the region of the knee. It is possible that the

condition may arise as the result of pain on movement after the injury. The condition should not give rise to difficulty in diagnosis, as there will be little wasting in the musculature of the thigh and leg, and all the contours of the knee-joint will be present. Any attempts to flex the knee will be defeated by the patient's spasm of the quadriceps. I have seen cases suddenly cured by forcible flexion without an anæsthetic. It is obvious that the diagnosis must be absolute before such treatment is undertaken. The position in these pseudo-ankylosed knees is not always that of extension; it is very common for men to assume the position of 30° of flexion deformity and to walk on the toes. Strong faradism to the quadriceps muscle will produce the desired effect in promoting the rapid voluntary extension. Re-educative treatment must be constant, and when the matter has been explained to the patient, he should be put into the gymnasium for graduated exercises. Rigid supervision is required, as many of these cases tend to relapse if a strict but benign influence be not constantly kept upon them.

FIG. 139.

(*d*) **Secondary Ankylosis.** A secondary ankylosis of the knee-joint very often occurs as the result of a compound comminuted gunshot fracture of the middle or lower third of the femur, producing traumatic tendon fixation. So much damage to the involved muscle may have taken place that the quadriceps extensor is bound down in the mass of newly formed bone, and an absolute rigidity of the knee-joint occurs.

In many cases the treatment of this condition is fraught with great difficulty, and the disability is a permanent one (Fig. 139).

Treatment. All cases of ankylosis should be X-rayed in two planes as a routine. Valuable information will be obtained thereby as to irregularities of the joint surfaces—the result of bone loss. The degree of cartilaginous erosion may be judged by the diminution in the spacing which occurs normally between the femoral and tibial elements of the joint (Fig. 140). This information is necessary, both for prognosis and treatment, with regard to future mobility in the joint.

Many cases of fibrous ankylosis display a genu recurvatum with marked lateral mobility of the joint. This is the result of damaged ligaments, and is generally due to injudicious exercise without adequate support at too early a date, or to postural treatment which allows the knee to hyperextend.

FIG. 140.

Whatever type of appliance is used in the early stages of treatment when the patient is in bed, posterior support to the joint by slings or a pad in the popliteal space is required.

The lateral mobility, above mentioned, is apt to become more marked as a further range of movement is obtained, and mechanical support will possibly be required for a prolonged period.

In fibrous ankylosis, where a forcible mobilization of the joint is decided, such treatment should be prefaced by a course of radiant heat

and massage for at least a fortnight. Firm effleurage should be given over all healed scars, but no passive movement should be given during the preparatory treatment. The behaviour of the scars under massage will often indicate as to whether the joint will react to forcible movement. Cellulitis or dermatitis may be produced. Should this occur, forcible movements should be postponed for at least two months, and meanwhile the joint should be immobilized by means of an appliance.

Should massage and radiant heat produce no ill effects, forcible flexion of the joint may be undertaken.

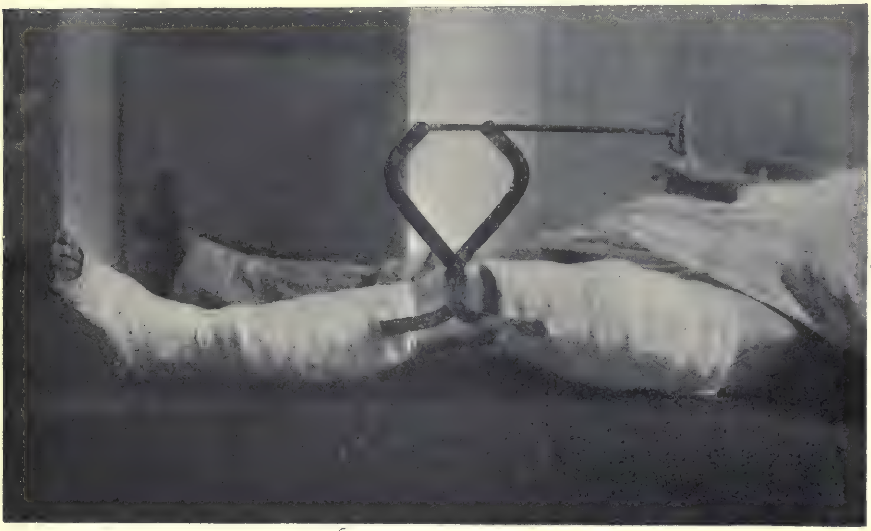

FIG. 141.

This may be carried out in one of two ways :

(1) Gradual forcible flexion by Turner's appliance.
(2) Rapid forcible flexion.

1. **Turner's Appliance.** A plaster-of-Paris cast is applied over well-padded bandages from the tip of the toes to the head of the fibula, the foot being at a right angle to the leg. Another cast, well padded under the tuber ischii, is now applied from one inch above the adductor tubercle to the groin, a broad ring-bearing surface being moulded beneath the tuber ischii, but the top of the cast should be well clear of the perineum. Turner's appliance is now moulded in the plaster so that the handle of the turning screw is facing uppermost. If one appliance only is used, it is better to fix it to the outer side of the joint (Fig. 141) ; but better results are obtained from the use of twin appliances, one fixed to the inner and the other to the outer side of the joint. The patient begins to flex his

knee by turning the screw which actuates the long levers. Pain is generally complained of after the screw has been turned and the knee begins to be forcibly flexed. When the patient takes a rest the pain tends to disappear; further screwing will produce further flexion. The patient takes his own time, and on account of the pain that he inflicts upon himself he is not

FIG. 142.—Vertical passage of bullet through knee, showing intra-articular fibro-osseous bridge. Suitable case for gradual forcible flexion.

likely to tear down any protective adhesions ruthlessly and so produce damage, but is more likely to stretch the fibrous tissue (Fig. 142). After a week or so the joint may possibly be flexed in the appliance to 20° or 30°, and the patient is able to screw the joint back into position of full extension without pain. The whole apparatus should now be taken off and the joint should be tested to discover whether the range of movement will decrease or not. The amount of voluntary movement that has

been obtained should now be measured by means of a goniometer. The patient should be kept in bed and receive no treatment except massage and radiant heat. The amount of movement should be carefully estimated from day to day, and if after a few days it is found to gradually diminish,

FIG. 143.

it is a definite sign that an active tissue reaction is taking place within the joint, and further forcible movements should be discontinued. Should the patient retain the amount of movement that has been forced, a second Turner's appliance can be fitted and the process repeated.

2. **Rapid Forcible Flexion.** Rapid forcible flexion under an anæsthetic may be utilized as a means of producing movement in fibrous ankylosis, but should be reserved for cases due to adhesions resulting from fractures of the femur, and should not as a rule be used when there has been a wound into the knee-joint due to a gunshot injury or operation for the

primary treatment of the same. The knee should be forcibly but carefully stretched, with the patient fully anæsthetized and lying on his face. Great care must be taken that the force be applied gradually and without 'jerking', otherwise the patella may be fractured. If adhesions tear with a snap, one may continue to flex for about 30° beyond the point at which the adhesion breaks. The knee-joint should now be immobilized on a posterior skeleton splint that is adjusted to fit the limb with the knee flexed to the degree that has been gained. Some swelling will probably occur in the knee-joint as well as local pain; these are the signs and symptoms of a reaction to the trauma that has been sustained. The joint must be immobilized until such a time as the tissue reaction has subsided, generally about five to eight days. Gentle massage may now be given and the splint taken off in the daytime so that the patient may begin to move his leg within the range of movement that has been gained for him, but the splint should be re-applied at night. Should the knee be found to have become fixed in the newly gained position, no further attempts should be made and the leg should be immediately brought back in the fully extended position so that it will be in the most advantageous position for a stiff knee. Should the movement of the knee-joint remain from extension to the point in flexion that was gained by the forcible treatment, a further series of treatments as described can be instituted, each of which is designed to gain from 30° to 45° of movement, and each must be succeeded by a corresponding period of rest. Should the knee be ankylosed in a position of slight flexion, it is always advisable to attempt to gain movement to full extension before any further range in flexion is attempted.

Fig. 144.

3. **False Joint.** Many cases arrive in orthopædic centres where so much bone has been removed, by primary operation in France, that 'flail joint' has resulted. The majority of these cases have undergone primary excision of the joint, and they arrive with so much gap between the cut ends of the bone, which is filled with dense scar tissue that no attempt at bony union can be hoped for (Fig. 143). The after-treatment of these

cases is difficult, on account of the trouble that is experienced in stabilizing the false joint by means of appliances and also by reason of the extreme shortening that is always present. Removal of the intervening scar tissue and the revivifying of the cut ends of the bone, with or without a bone graft to produce arthrodesis, appears to be the best procedure. The use

FIG. 145.—Three months after excision--discharging wound.

of a jointed appliance has been recommended, but has not been at all satisfactory in my experience.

In cases unfavourable for operation, a calliper splint with an elevated boot will be required (Figs. 144, 145, and 146).

Treatment of Wounds of the Knee-joint. Primary treatment at the seat of war has been outlined.

It is necessary to emphasize that all cases must be immobilized from the outset, and that it is of paramount importance that joint fixation be

absolute during transportation from Base Hospitals abroad to hospitals in this country. Often wounds of the joint that arrive in Orthopædic Centres are either those in which no suture has been possible in France, and in which the septic process is advanced, or those in which primary excision and suture have failed on account of inefficient fixation during

FIG. 146.—Same case five months later, showing formation of sequestrum.

transportation (Fig. 147). In both types the usual symptoms of arthritis in a closed joint are absent, as there is no intra-articular tension.

Rapid disintegration of the joint with progressive constitutional disturbances are apt to occur and necessitate prompt and radical operative measures. Such cases should be incised and drained effectively—as a rule in four quadrants—one on either side of the patella into the anterior compartment of the joint, and two posteriorly, one on either side of the posterior crucial ligament. Constant lavage by the Carrel-Dakin method

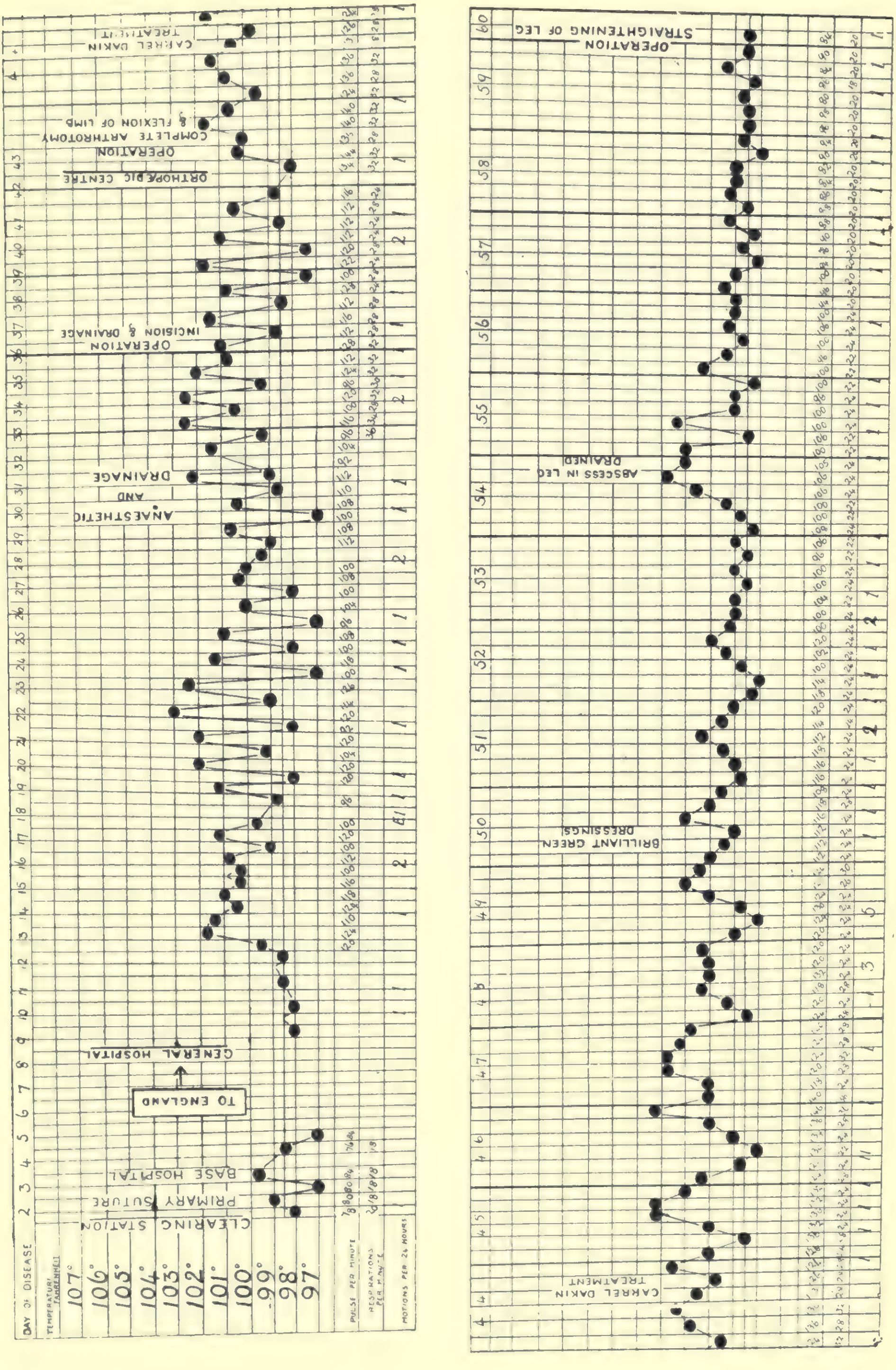
DAY OF DISEASE
TEMPERATURE FAHRENHEIT
107° 106° 105° 104° 103° 102° 101° 100° 99° 98° 97°
PULSE PER MINUTE
RESPIRATIONS PER MINUTE
MOTIONS PER 24 HOURS
CLEARING STATION
PRIMARY SUTURE
BASE HOSPITAL
TO ENGLAND
GENERAL HOSPITAL
ANAESTHETIC AND DRAINAGE
OPERATION INCISION & DRAINAGE
ORTHOPÆDIC CENTRE
OPERATION COMPLETE ARTHROTOMY & FLEXION OF LIMB
CARREL DAKIN TREATMENT
BRILLIANT GREEN DRESSINGS
ABSCESS IN LEG DRAINED
OPERATION STRAIGHTENING OF LEG

FIG. 147.

should be carried out, and a tube, in addition to the four above mentioned, should be inserted into the suprapatellar pouch.

In such cases of septic arthritis where one is doubtful as to the efficacy of the treatment as outlined above, the leg can often be saved by means of a complete arthrotomy and fixation in the fully flexed position. A large

FIG. 148.

J-shaped incision should be made, the long stem being on the outer side of the joint. The infrapatellar ligament is divided, the patella and all the anterior structures are raised up. The anterior and posterior crucial ligaments are divided and the entire knee-joint opened to view. All subsidiary pockets of pus in the fascial planes should be opened up. The heel is tied into the buttock and the joint is thereby flexed to an extreme degree. Four to six Carrel tubes should be placed over the articulation and the case treated by the continuous drip method. As a rule the remnants of articular cartilage will soon disintegrate and healthy granulation tissue will be laid down after a few days. Carrel

treatment should continue until the condition becomes clinically clean. After about ten to twenty days another anæsthetic may be given and the leg fully extended and immobilized in a Thomas bed-splint with a foot-piece and the knee allowed to ankylose in a suitable position. The chart (Fig. 147) portrays the progress of such a wound from its inception. The

FIG. 149.

treatment of such cases depends on the condition of the patient. Should the surgeon come to the conclusion that the patient will not stand the treatment that has been outlined, emergency amputation is indicated. This is best performed in bed with nitrous oxide and oxygen anæsthesia.

Secondary Excision. Where it is felt that by reason of pain, disability, or malposition a firm ankylosis in a suitable position has not been gained, and where no recovery of movement is expected, an excision of the joint, delayed for a sufficiently long period of time to obviate any danger

with regard to septic recrudescence, should be undertaken. This incision should aim at producing a sound bony ankylosis with sufficient bone surfaces in close proximity to one another to make the synostosis firm enough for all subsequent weight-bearing. Where so much bone has been removed from a condyle or tuberosity at the primary operation as to

FIG. 150.

necessitate the removal of an undue amount of bone to get a satisfactory union, it is advisable to build up the hiatus by means of bone transplants taken from the opposite condyle or tuberosity (Figs. 148 and 149).

The desired result will thus be gained without unnecessary shortening of the limb. Post-operative fixation by splint or plaster of Paris is a matter of individual choice, but a bracketed plaster as shown in the illustration has been of great service to me in many cases, and does not produce so much pain during subsequent dressings as other methods that have been tried (Fig. 150).

The question as to the position in which the leg should be placed

after excision of the joint is open to argument. Ten degrees of flexion will enable the patient to walk with less limp than one that is put in extreme extension. It is, however, very necessary to point out that if the position of slight flexion be used, great care must be taken during the time the patient is first walking that the flexion angle does not increase. Post-operative immobilization for at least sixteen weeks should be the rule.

FIG. 151.

Splints and Appliances. Cases of wounds involving the knee-joint should be treated in a well-fitting Thomas bed-splint. Extension should be applied by means of lateral extension straps and the foot should be immobilized in the foot-piece which keeps the foot at a right angle, prevents subsequent flexion of the toes, and at the same time steadies the splint in the bed. Great care must be taken to prevent posterior 'sagging' of the knee; the bandages that are used to sling the leg must be kept at their correct degree of tension by means of Sinclair clips. Should a back splint be used instead of slings, a pad in the ham will be necessary. When the general septic condition is well in hand, the bed-splint should be transformed into a walking calliper used in conjunction with one of the light type of boots supplied through Army sources. The calliper should be made of sufficient length to prevent any strain being cast on the surfaces of the knee-joint, all the weight-bearing being taken by the tuber ischii. Where a bony ankylosis has taken place, it is advisable to use the calliper splint for at least two months after union has taken place. This will prevent the flexion deformity that invariably takes place if weight-bearing is permitted without adequate mechanical support before bony union is absolutely sound. Should it be deemed that a calliper is unnecessary, a leather-laced support (Fig. 151) can be made to accurately fit the knee and leg; this acts as a ferrule, and, by reason of the steel stem that is incorporated in the leather, will prevent any undue strain being thrown on the limb while walking. The Marsh cage splint is of great use where limitation of movement is desired; this appliance can be made to permit of any or no degree of movement.

ANKLE-JOINT AND FOOT

(TRAUMATIC AND NON-TRAUMATIC DISABILITIES)

BY

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ANKLE-JOINT AND FOOT

THE erect attitude of man demands that the human foot shall be an organ for balancing the body in a much greater degree than in most other animals. Many of the disabilities of the foot and ankle are due to conditions disturbing its proper balance and therefore giving rise to complaints of pain or weakness from undue strain of such structures as ligaments and joint capsules or undue pressure on bony structures and the parts covering them.

On examining the mechanism of the foot it is found to be divisible into several elements in each of which disturbances of balance with corresponding disturbances of function may occur, and when it comes to treatment the same principles apply whether the original cause is direct trauma or some other disturbing factor.

ELEMENTS OF THE FOOT

The main elements are:

1. The ankle-joint;
2. The hind part of the foot;
3. The mid-tarsal joint and longitudinal arch of the foot;
4. The fore part of the foot;
5. The transverse arch of the foot, which is contained wholly in the fore part of the foot.

Besides the disturbances of function due to disorders in these parts there are other troubles located in the toes or particular joints such as the subastragaloid or the first metatarso-phalangeal joints, which will be dealt with separately later.

Most practitioners recognize such conditions as hammer toe or hallux rigidus or valgus without difficulty, but many complaints of pain or disability which are made by patients are often due to less obvious causes depending on disturbances of the proper balance between the main elements of the foot.

It will be easier first to make a brief examination of the anatomical structure and principal function of each of these elements in relation to weight-bearing and balance.

THE ANKLE-JOINT

1. The body weight is transmitted downwards in a vertical line through the hip- and knee-joints down the tibia to the ankle-joint, which is formed by the tibia, the external malleolus, and the astragalus.

Before examining the ankle-joint further a definition must be given of what is meant by the ' hind part ' of the foot.

2. The hind part of the foot consists of the astragalus and os calcis. In the normal foot these two bones are so closely bound together that for practical purposes they are to be regarded as a mechanical unit situated behind the mid-tarsal joint and may conveniently be called the hind part of the foot.

The ankle-joint is really the articulation between the tibia and external malleolus on the one side and the hind part of the foot, not only the astragalus, on the other. This wider definition is necessary because the lateral stability of the joint is secured not merely by internal and external malleoli which are lateral buttresses to the astragalus but also by the strong lateral ligaments of the joint which are attached below to the sides of the os calcis.

Movements. 1. Antero-posterior hinge movement in which the tibia glides backwards and forwards over the arched dorsum of the astragalus. A glance at an astragalus will show that the centre of this arch is situated low down quite near the sole of the foot ; it is therefore obvious that the hinge, which most instrument-makers are so fond of making in side-irons and other similar appliances, situated opposite the malleoli is anatomically wrong, and that the simple socket in the heel used by surgeons of the Liverpool School though not mathematically correct in position is mechanically much more efficient and has the further merit of being simpler and cheaper.

2. Lateral movements are more limited. The considerable degree of abduction of the hind foot which appears possible, bringing the ankle into a position of valgus, is a combination of movements at the ankle and astragalo-calcanean joints.

The balance of the leg on the foot at the ankle-joint is very important. The lateral balance depends mainly on two factors, the integrity of the lateral ligaments and, second, the correct alinement of the malleoli and the hind foot with the vertical line through which body weight is transmitted. Strain of the internal lateral ligaments allowing a valgus deformity at the ankle is an element in some of the more severe cases of ' flat-foot ', and is to be dealt with by measures similar to those to be described later when dealing with the treatment of ' flat-foot '. Lateral deviation due to faults in alinement of the malleoli is frequently seen in connexion with fractures of the bones of the lower fourth of the leg.

(*A*) The most common is in connexion with fracture of the lower fourth of the fibula, when a traumatic valgus is the result sometimes of incomplete reduction of the original abduction deformity more often of want of judgement in the after-treatment. Many cases of this type

occur from gradual yielding of the callus at the fracture after the patient is allowed up.

Treatment. 1. *Prophylactic.* Every Pott's fracture, or any of the complicated varieties of this fracture, should have the heel of the boot raised $\frac{1}{4}$ to $\frac{1}{3}$ in. on the inner side to keep the hind foot adducted or slightly in a varus position. If the patient is heavy, 11 stone or over, he should have an outside iron and inside T-strap as well.

2. *Corrective.* If the condition has already occurred, treatment varies according to the stage at which advice is sought.

(*a*) In the early stage, say six to ten weeks after the patient begins to walk, if there is local tenderness on pressure over the site of fracture in the fibula, the callus will probably yield to adaptive changes induced by altering the balance of the foot by raising the inner side of the heel of the boot and applying an outside iron and inside T-strap. (Fig. 152.)

(*b*) Under an anæsthetic the hind foot may be wrenched into a varus position; sometimes it is necessary to divide the middle slip of the external lateral ligament in addition to wrenching the foot. The grip of the Thomas wrench for this manipulation is on the sides of the os calcis immediately below the malleoli with the tendo Achillis resting on the shank of the wrench; it is necessary to screw up the wrench very tight to prevent the jaws from slipping.

FIG. 152.—Outside iron and T-strap to prevent valgus at the ankle after fracture of the leg.

(*c*) *Operative Treatment.* (1) Some surgeons perform osteotomy of the fibula at the site of the original fracture and wrench the foot into inversion and treat the case *de novo*.

(2) Another method which is more widely applicable is to remove a small wedge from the base of the internal malleolus, perform a simple osteotomy of the base of the external malleolus, and then wrench into correct position.

(*B*) Deviation of the hind foot into a varus position at the ankle follow-

ing fracture is usually the sequel to fracture of both bones low down, near the malleoli. The operation just described of performing a wedge osteotomy on one malleolus and a simple osteotomy of the other should always be remembered in cases in which wrenching, correction in plaster, and subsequently allowing the patient to walk with a lateral iron T-strap and crooked heel is not sufficient to restore the balance of the joint. In all cases after corrective treatment the patient should wear a side-iron T-strap and crooked heel for at least three months after treatment in bed and in plaster of Paris is finished.

Antero-posterior stability at the ankle-joint depends on the tendo Achillis and calf muscles behind and, in front of the ankle, on the mechanical leverage of the foot as well as on the extensor group of muscles. The important rôle played by the mechanical leverage of the foot is well illustrated by a brief survey of the cases of amputation through various parts of the foot which have been performed during the war after frost-bite or gunshot injuries. In cases of amputation through the mid-tarsal joint (Chopard's amputation) it has almost invariably been necessary to re-amputate by Syme's method, because, although a Chopard's amputation may seem satisfactory at first, the balance at the ankle cannot be maintained. The combined action of the pressure of the ground on the heel and the muscular action of the calf muscles cannot be balanced by the pull of the anterior group of muscles on the short lever formed in front of the ankle by the head and neck of the astragalus. When the amputation of the foot is through some part of the metatarsals in front of their bases it is possible, by arranging a bar across the boot to prop up the metatarsal stumps, to get enough leverage in front of the ankle to enable the balance to be maintained against the leverage of muscle and upward pressure of the ground behind. This bar must be arranged so as to avoid pressure on the end of the stump, which is often tender ; if this cannot be done it is better to perform a Syme's amputation without hesitation. All amputations of the foot in which the heads of the metatarsals have been removed require some kind of transverse bar just behind the ends of the metatarsals to assist in maintaining the counter-balancing leverage, otherwise the fore end of the foot is depressed too hard against the ground by the leverage behind the ankle, and in these cases the end of the stump is often tender to begin with. In amputations through the metatarso-phalangeal joints this is no longer necessary as the normal length of lever is present—unless some sort of bar is needed to avoid pressure on a tender spot as in cases of metatarsalgia (v. *infra*). (Figs. 153 and 154.)

Disabilities due to limitation of movement at the ankle-joint.

The only disability which need be considered in this connexion is limitation of dorsiflexion, for even if an ankle is quite rigid with the

foot at an angle of 90° or rather less the patient can walk comfortably and well.

The slightest degree of equinus deformity is at once a disability, for in normal walking the heel does not leave the ground till the knee is well

FIG. 153.—Shows amputation for frost-bite. The patient could barely hobble about on account of equino-varus deformity of the right foot, which made him put weight on the end of the foot. The left foot is illustrative of the bad result which frequently follows Chopard's amputation.

over the fore part of the foot, i. e. till the foot is dorsiflexed to considerably under a right angle. The foot is again dorsiflexed as it swings past the other foot.

The cause of the equinus may be due to :

1. Shortening of the calf muscles due to prolonged fixation or to spasm ;

2. Contracture of scars in the calf muscles ;
3. A bony block between the front edge of the tibia and the neck of the astragalus ;
4. Fibrous ankylosis in and about the joint due to septic infiltration ;
5. Bony ankylosis of the joint due to direct injury or to septic infection.

FIG. 154.—Shows right foot after correction by wrench and plaster, and the left after a Syme's amputation had been performed. The patient walks comfortably with a bar on the sole behind the ends of the metatarsals of the right foot.

Treatment consists in bringing the foot into dorsiflexion to less than 90°, the only question being whether or not movement at the ankle can be preserved or restored, and if so how to secure the most free and useful movement.

Treatment. 1. Never perform a complete tenotomy of the tendo Achillis. If the calf muscles are short they should be elongated either by (*a*) exercise, passive stretching, re-education and suggestion for the

functional element if present, or (*b*) if too obstinate for this by stretching with the Thomas wrench under an anæsthetic and fixation in plaster in a dorsiflexed position allowing the patient to walk in the plaster for not less than a fortnight before removing the plaster, or (*c*) if the case will not yield to this elongation of the tendo Achillis by splitting the tendo Achillis and dividing one-half low down and the other half higher up and then sliding the two halves over each other. When in doubt it is wise to perform an open operation; it can be done subcutaneously with a tenotomy knife, but this requires a little skill and practice in the use of the tenotome to make sure of performing the operation neatly and successfully. A few cases in this group may be treated by the method recommended for the next group.

2. In cases in which the equinus deformity at the ankle is due to extensive scarring and consequent contracture of the calf muscles, the question arises whether it will be best for the patient to get the foot to a right angle by elongating the tendo Achillis or by gradually stretching the scar.

At first sight it appears that elongating the tendon is the quicker procedure, but it must be remembered that the patient must go about in plaster for four weeks and after that it will be another six or eight weeks before his foot attains its full strength. The arguments against operating on the tendo Achillis are first that when the scarring on the back of the leg extends down round the tendon it is a very difficult operation; the second objection is still more important, for elongating the tendon means abandoning all hope of stretching the scar in the muscle above and obtaining regeneration of disused muscle fibres.

In these cases the writer therefore prefers to attempt to stretch the scar by the device known at the hospital at Shepherd's Bush as a 'drop-heel' plaster. The technique of this is fully described in the chapter on splints and plaster (vol. ii). The results of this procedure have in many cases surpassed expectation, and the method has been adopted in suitable cases by several other surgeons.

3. Bony blocking of the front of the ankle-joint preventing full dorsiflexion is a frequent occurrence and arises in several ways.

(*a*) It is a frequent complication of Pott's fracture, where it is generally due to incomplete reduction of the backward displacement of the astragalus. This can generally be corrected if seen in time by forcible dorsiflexion under an anæsthetic. In performing this reduction as in stretching the tendo Achillis the grip with the Thomas wrench is with one jaw on the front of the ankle-joint against the lower edge of the tibia and the other under the tarso-metatarsal joints; thus, one jaw pushes the tibia backwards and the other lifts the whole tarsus forwards and upwards.

(*b*) Pott's fractures and fractures of both bones at the lower end of the

leg are frequently complicated by a fracture of a scale of bone off the front edge of the tibia ; this is apt to slip down and block against the neck of the astragalus. A similar blocking occurs as the result of formative periostitis due to bruising of the periosteum in cases of fracture or in severe twists or wrenches of the ankle without fracture. No trouble results if the foot is properly dorsiflexed when the injury is first treated. Similar splinters of bone or outgrowths of new bone may obviously arise from local gunshot wounds.

Treatment. When a bony block has occurred it may still be possible to overcome the difficulty by wrenching the foot into dorsiflexion and fixing it there in plaster for six weeks. If not recognized till it is too late for this treatment there is no cure for the condition except operation to remove the offending projection of bone. Good access is obtained by a longitudinal incision down to the joint on one or other side of the group of extensor tendons and reflecting all the soft parts to the sides to expose the bone. After the bony projections have been removed with chisel or gouge the foot should be put up in dorsiflexion. The writer usually puts the foot in full dorsiflexion in a clubfoot shoe-splint till the stitches are taken out, then in plaster at an angle of about 80°, and allows the patient to walk about two or three weeks after the operation ; the plaster should be left on at least a month.

4. **Fibrous Ankylosis** in faulty position is usually the result of sepsis either following local trauma or as a secondary infection. In these cases it is again necessary to bring the foot to a right angle. No forcible measures should be adopted for several months after all septic manifestations have ceased.

Two definite clinical varieties may be recognized. (1) Cases in which on manipulation it is obvious that the ankylosis is not bony, because a slight degree of movement is present limited by an elastic resistance to passive movement, not the sudden stop of a bony block. In this type the X-ray may be expected to show clear joint surfaces indicating that the fibrous adhesions are round about the joint more than within the joint. There is generally a complaint of pain after walking due to straining of the fibrous adhesions. Such cases will generally yield to a determined attack with the wrench, after which the after-treatment should be either (*a*) massage movement and graduated exercise or (*b*) fixation in plaster in a corrected position at or just under a right angle. The choice between these two depends on what the surgeon feels when moving the joint. (*a*) If he feels several firm bands of adhesion snap one after another, leaving the joint freely movable, he may go on at once with massage and movement, but must be prepared to fix the foot in plaster if this treatment produces increasing stiffness and increasing pain. (*b*) If, on the other hand, the position of the foot is only corrected with difficulty,

and all fibrous obstruction is not completely broken down and the joint does not become freely movable, the foot and leg must be fixed immovably, in plaster, because the fibrous bands will contract again unless they are fixed in full extension. In such cases the patient will complain of great pain afterwards, and will require morphia for twenty-four to forty-eight hours until the tense bands of scar tissue undergo adaptive lengthening to the new position.

(2) The second clinical type is one in which the surgeon may be excused for not being quite sure whether the ankylosis is not bony. That is to say, the joint seems rigid on manipulation but perhaps does not give the impression of the stony hardness of osseous union. The X-ray appearance in such a case is generally that the joint space between the bones seems filled up with faint laminated lines parallel to the joint surfaces, indicating that there is fibrous tissue binding the bones together within the joint. This appearance is best seen in a lateral view, showing the laminæ running parallel to the arched dorsum of the astragalus.

In these cases it is only sometimes possible to correct an equinus position by wrenching under an anæsthetic, for there is an extensive area of fibrous adhesion between the bones. If position is successfully corrected the foot should be kept in correct position in plaster for several weeks. Some cases have yielded to the gradual extension treatment in drop-heel plaster, the foot not only coming into a correct right-angled position but also recovering some movement at the ankle-joint. It is, therefore, well worth while to consider and try this method of treatment before resorting to a cuneiform resection such as is described below for cases of osseous ankylosis.

5. **Bony ankylosis** of the ankle-joint in faulty position can only be corrected by operation. In addition to the equinus deformity which has been taken as the type most commonly requiring correction there may be lateral deviation, the treatment of which has already been described.

Diagnosis is made by the absolutely stony hardness of the resistance to manipulation and the fact that in the X-ray picture lamellæ of bone can be seen running down from the tibia into the astragalus and in cases of wide septic involvement of the tarsus on to the scaphoid and cuneiform bones. These appearances are best seen in a lateral view of the joint.

It is necessary to remove a wedge of bone from the region of the ankylosed ankle-joint in every case to allow the foot to be brought to an angle of 80° to 90° with the leg so that the patient may walk in comfort. The only questions are when is it permissible to operate and in what circumstances is it permissible to attempt to restore a movable joint. It may be said that it is wise to wait at least six months after the last trace of sepsis has disappeared before performing any operation, and longer if a new joint is in view.

With regard to the question of making a new joint, the cases most suitable are those in which the osseous ankylosis is the result of secondary sepsis without necrosis of bone and in which the X-ray picture shows well-defined lamellæ of bone running from the tibia to the astragalus. In cases of gunshot wound through the ankle with shattering of bone, necrosis and sepsis, the operation of arthroplasty is not so likely to be successful.

The final decision can be made on the operating table.

Operation. The front of the ankle-joint is exposed. The writer employs a longitudinal incision avoiding the tendons and strips the soft parts as far as the malleoli with a periosteum elevator. The elevator is then used as a retractor on each side. The original position of the lower edge of the tibia is defined and a broad arthrodesis gouge is driven in shaping out the interval between the malleoli removing about $\frac{1}{4}$ in. of the tibia. The gouge is next entered lower down on the astragalus so as to take out a wedge, consisting of a small portion of the tibia above and the upper surface of the astragalus below. If the bone is so dense that it can be cleanly carved out, making a new upper surface of the astragalus fitting easily between a new notch between the malleoli, a false joint may be attempted. If any soft crumbling bone of an osteo-arthritic type is found, ankylosis is almost inevitable, and in any case a painful joint is almost sure to result. Therefore if the bone is not quite firm and does not carve cleanly with a sharp gouge, it is wise to put raw bone to raw bone without any further delay and aim at a firm ankylosis.

If the case is suitable for arthroplasty a considerable pad of fat is usually to be found behind the transverse part of the annular ligament behind and to the outer side of the tendons. This should be carefully preserved in the early stages of the operation, for if it is intact a large flap can be turned down nearly sufficient to cover the whole articular surface of the tibia.

The writer's plan of after-treatment is to stitch the wound up in layers and put the foot in a club-foot shoe bent to about 80°. Three days later without undoing the bandages the patient is asked to try to move his ankle and is encouraged to use the muscles. The stitches are removed on the tenth day and the patient is asked to show if he can move the ankle. If he can do so the operation will probably be successful ; but if the joint is too painful and stiff for the patient to move it, the result will probably be an ankylosis.

No passive movement at all is attempted at any stage. The foot is then put in plaster of Paris in the same position. The patient is allowed to put it to the ground and walk about three weeks after the operation ; the plaster is renewed when necessary at intervals of about six weeks. No passive movement is attempted when renewing the plaster, but the

patient is allowed to move the foot voluntarily. A succession of plaster splints is applied for at least four months. This is to prevent jarring the joint and setting up osteo-arthritis. Of the writer's cases six have been performed more than twelve months ago. One ankylosed at once, one had a long period of osteo-arthritis and fortunately became quite stiff and free from pain. Of the other four one had free movement through a range about three-quarters that of the other foot eighteen months after the operation and was doing a whole day's work without pain, the other three were free from pain but had not such a good range of movement.

All these were performed on specially selected cases with the patient's permission after it had been pointed out to him that a stiff ankle in good position was a good painless ankle, but an ankle with movement but some arthritis is a bad painful ankle which can only be cured by another operation to make it stiff and secure.

One word in conclusion, though it seems a paradox, if the patient can move the ankle at all at the end of ten days then the longer it is kept fixed in plaster with the patient walking on it the better the final result seems to be.

THE HIND PART OF THE FOOT AND THE MID-TARSAL JOINT

The hind part of the foot, consisting of the astragalus and os calcis, articulates in front with the fore part of the foot at the mid-tarsal joint, which is in two portions, an inner part—the astragalo-navicular joint, and an outer part—the calcanco-cuboid.

These two parts of the mid-tarsal joint belong respectively to the two separate components of the longitudinal arch of the foot, and their architectural form and function must be grasped in order to arrive at a clear comprehension of the complex strain of the foot commonly referred to as flat foot.

Roughly the instep or hollow of the foot forms a half dome; when the two feet are placed close to each other they together form a dome, not circular but rather ellipsoidal in shape. Looked at in this way the dome formed by the two feet together rests on the ground all round the edge of the dome from the heel of one foot round the outer border of the foot along the toes and back along the outer border of the other foot to the heel. Each foot by itself, if we take this view, is only half a dome resting on its outer rim ; it is therefore stable if the body weight is so balanced that it rests on the outer edge of the foot or half dome, but if the body weight falls too near the inner side of the half dome there is a tendency for it to capsize inwards. This capsizing inwards is the essential mechanical factor in the pathological condition known as flat foot. The mid-tarsal joint running across the foot is so constructed that the joint

is twisted if the foot capsizes inwards. In consequence of this twisting, ligaments are unduly stretched and sometimes bones are unduly compressed against each other producing localized pain or tenderness.

The Two Components of the longitudinal Arch. On a consideration of two components of the longitudinal arches of the foot it is to be noted that the outer component consists of the os calcis behind, the cuboid in the middle, and the fourth and fifth metatarsal bones in front, and is supported on the heel behind and the heads of the two metatarsals in front.

The joint surfaces between the os calcis and cuboid are saddle-shaped, allowing a limited degree of movement in flexion, extension, abduction, adduction. The surfaces between the cuboid and the bases of the metatarsals only allow a slight gliding movement. The outer part of the longitudinal arch is a low flat arch with fairly stable joint mechanism; when the man carries a heavy load the arch flattens still more till practically the whole length of the arch is on the ground. It is clear, therefore, that the range of movement and the stability of this part of the mid-tarsal joint are such that it is not likely to be the site of painful symptoms in the strain of the foot known as flat foot.

The inner component of the arch presents very different architectural features. In the first place, the number of joints in it is greater than in the outer part; further, the mobility of the mid-tarsal joint in this part of the arch is much greater. The arch rests on the heel behind, rises steeply forwards to the neck of the astragalus, and then turns downwards and inwards passing forward through the head of the astragalus, the scaphoid and the three cuneiform bones to the three inner metatarsals, and rests in front mainly on the head of the first metatarsal. Looking first at the portion of the mid-tarsal joint contained in this part of the arch, it is to be noted that it is a ball and socket joint between the head of the astragalus and the scaphoid. The movements at this joint are therefore free in all directions, including rotation, limited only by the retaining ligaments. The remaining joints between the scaphoid, cuneiform bones, and bases of the metatarsals have nearly flat joint surfaces permitting only small gliding movements limited by strong ligaments. Along with the large movements at the astragalo-scaphoid joint smaller accommodating movements occur at the calcaneo-cuboid joint and all the other joints of the tarsus and metatarsus.

It has already been stated that the pathological condition commonly known as 'flat foot' depends essentially on a capsizing of the foot inwards. When this happens the thrust of the body weight downwards on the astragalus resisted by the upward thrust of the ground on the heel and the ball of the foot does not merely extend the foot at the mid-tarsal joint, but abducts and pronates the foot at the astragalo-scaphoid joint.

The two latter movements when continued to the point of straining

the ligaments produce the symptoms of pain, and when the ligaments are overstretched there is undue laxness of the joint. Hence the subject of ' flat foot ' has frequently been discussed under the headings of ' weak foot ', ' pronated foot ', ' abducted foot ', or ' everted foot '. All these terms are correct descriptions of part of the deformity present in every case of pathological ' flat foot ' ; the degree in which each element occurs varies in different cases. Before proceeding further, an absolutely clear distinction must be made between a foot with a low arch, i.e. a foot which looks flat, and a capsized foot, which is the site of a pathological condition known as ' flat foot '.

People with flat feet seldom or never suffer from ' flat foot ' as a pathological condition.

To illustrate this point it may be mentioned that in the early days of conscription the Orthopædic Hospital at Shepherd's Bush was inundated with recruits sent in from training camps suffering from painful ' flat foot '. Some people thought that many of these cases must be malingerers. Among those who held this opinion were several medical officers home on leave from France, whose statements were almost always something like this : ' I assure you that 75 per cent. of the men in the battalion I have been with in France have absolutely flat feet, but can march and carry their packs ; and, look at their record.' At the time the writer was only able to argue in general terms on the difference between low arches and strained arches. It was only later that what may be the possible explanation presented itself. In nearly every instance the battalion mentioned was a territorial unit raised in an agricultural county. It is therefore fair to presume that the majority of the men were agricultural labourers—' clod hoppers '—who from childhood had worn heavy stiff hobnailed boots and been early inured to carrying considerable weights, and further had never used the spring of the arch of the foot. The result of the heavy stiff boot allowing little or no spring in the foot, and heavy work from childhood, is that their arches have gradually become lower and lower, the foot being extended but not twisted at the mid-tarsal joint. Mechanically it is obvious that a low arch is less likely to be capsized than a high arch.

The recruits that broke down were drawn almost entirely from the office-boy class who had been accustomed to light flexible boots and had high arches to begin with. They were made to thrust flexible feet into stiff-soled army boots, and to stand and drill in stiff boots to which they were not used, and their feet gave way. Once their ligaments began to stretch and give pain, the downward path was too often rapid. Sometimes they were excused drill and put on light duty ; in one instance that came under the writer's care ' light duty ' consisted of removing refuse bins and making himself useful carrying things to and from the kitchens.

Had he been a horse he would probably have been put out to grass and intelligently got into condition before being worked.

'Flat Foot'. It has already been stated that the pathological condition commonly referred to as 'flat foot' is essentially a capsizing of the foot to the inner side associated with varying degrees of abduction and pronation. (*v.* Fig. 155, left foot.)

FIG. 155.—This case suffered from 'trench feet', the sequel being a typical flat foot' on the left side and a typical 'claw foot' on the right.

The foot is supported on three points: the heel and the first and fifth metatarsals. If the vertical line down the tibia falls well within these three points as the patient walks, the fact that he has a low flat longitudinal arch is in itself of no significance. On the other hand, if the fore part of the foot is abducted and the vertical line down the leg falls well on the inner side and the scaphoid tubercle can be seen rolling downwards and inwards as he walks, it means that the patient's arch is giving way and his complaints of pain and weakness in the foot are probably true.

The pains characteristic of varying degrees of yielding of the longitudinal arch are:

1. Pain and tenderness under the tubercle of the scaphoid due to stretching of the inferior calcaneo-scaphoid ligament.

2. Pain across the dorsum of the tarsus; this is often as early a symptom as the former, and appears to be due to straining of the ligaments binding the cuneiform bones to each other and to the scaphoid, or to compression of the upper edges of the articular surfaces. In some cases passive pronation of the foot seems to produce the pain and sometimes dorsiflexion, the former suggesting stretching of ligaments when the foot is twisted as the cause of the pain, the latter rather indicating compression of the joint edges.

3. Pain in the muscles, especially the tibiales muscles, may be an early symptom, and is due to fatigue of these muscles caused by an effort on their part to relieve strain on stretching ligaments.

4. In cases with much eversion of the foot and associated valgus deformity at the ankle, pain is sometimes complained of at the tip of the external malleolus or on the side of the os calcis below it. This is due to the two bones touching each other and bruising the intervening periosteum and soft parts. Sometimes an adventitious bursa forms at this point. The diagnosis is confirmed by eliciting local tenderness on palpation, and by everting the foot; while dorsiflexion with the foot inverted causes no pain; and finally, it may be possible to feel either local œdema or a small bursa. This is to be carefully distinguished from pain due to adhesions following a sprain of the external lateral ligament. These are often associated with a flat foot secondary to the trauma. Pain is elicited by inverting not by everting the foot. The indication is therefore to break down the adhesions before altering the boots to regulate the balance.

5. In acute cases the whole foot may be too tender and painful for the patient to stand or allow it to be handled.

The bones forming the arch of the foot are maintained in position by the ligaments connecting the several joints, but muscular action plays a subsidiary part. The muscles chiefly concerned in helping to support the arch are first the two inverters of the foot and ankle, namely, the tibialis posticus and tibialis anticus muscles. The tibialis posticus is inserted first into the tubercle of the scaphoid and then by a radiating series of digitations to all the bones of the tarsus except the astragalus and the bases of all the metatarsal bones except the first and the fifth; when the muscle contracts this radiating insertion forms a sort of hammock or sling holding up the instep. The tibialis anticus is inserted low down on the inner aspect of the internal cuneiform bone and to the adjacent part of the base of the first metatarsal. Its action, therefore, is to pull the first cuneiform and base of the first metatarsal upward and

inwards, and both muscles produce a rotation between the astragalus and scaphoid, a movement which by analogy with the hand may be called supination of the fore part of the foot.

The second muscular support of the longitudinal arch of the foot is to be found in the short muscles of the sole, especially those rising from the inner tubercle of the os calcis, viz. the abductor hallucis and the flexor brevis digitorum, which run in slips from the tubercle of the os calcis, one slip to each toe; thus each slip forms a stringer or bowstring to the component of the half dome formed by the respective metatarsals and their connexions back to the heel. The action of these muscles on the mid-tarsal joint is to flex it.

It has been stated above that the support given to the arch by the muscles is subsidiary to that given by the ligaments; one significant piece of evidence on this point is that many cases of strain of the arch complain in the early stages of pain when standing but not when walking; the explanation being that in action the muscles have control, but at rest the muscles relax and the strain comes on the ligaments. The lesson to be drawn from this is that one cannot count on exercises to cure the condition; something must be done to relieve the ligaments of strain when the muscles are relaxed. The conclusion, therefore, is that exercises are a subsidiary part of the treatment, but altering the balance of the foot is of primary importance. The essential factor in treatment is to deviate the body weight off the inner part of the arch on to the outer more stable portion. This can be done by raising the inner side of the heel and sole of the shoe $\frac{1}{4}$ to $\frac{1}{3}$ of an inch, so as to tilt the whole foot to the outer side.

Treatment of Flat Foot. The method of setting about the treatment of a case of flat foot depends on the type of case. One clear division can be made at once into those cases which can be immediately relieved by altering the shoes and those which require some other preliminary preparation.

If the patient can voluntarily invert his feet so that he stands on the outer edge of the foot, it may be taken as a rule that in nearly every case he can be made comfortable by slanting the heel of his boot so that when standing with muscles relaxed his weight is on the outer side of the foot. If the patient cannot voluntarily stand on the outer edge of the foot the reason must be sought for, and will be found to be either (*a*) there is a paralysis of muscles which is outside our present discussion, (*b*) the foot is so acutely tender that he cannot bear the strain of muscular action, or (*c*) the foot is too stiff to be inverted by voluntary muscular action.

It is possible, therefore, to classify cases into three groups:

1. Acutely painful feet in which the arch has collapsed.
2. Rigid flat foot in which the arch has collapsed and become rigid; this may be a sequel to an acute flat foot.

3. Mobile cases in which the arch is giving way, is tender when strained, but is still under muscular control.

The object of treatment is to convert the first two types into the third type and then follow standard rules of treatment which are applicable to the third type.

1. An **acute painful flat foot** is one in which the ligaments are being rapidly stretched ; it is therefore particularly liable to occur in people with naturally high arches and of heavy build who for any reason have their ligaments too weak to withstand the strain.

In civil life examples of this type are frequently found during influenza epidemics, for instance among nurses. Thus a nurse has had influenza and is convalescent, she ought to go away for a change, but the staff is so reduced by other nurses falling ill that she goes on duty and stands and works on ligaments and muscles that are not in condition to withstand the strain ; that night her feet are aching so much that she cannot sleep for a couple of hours, each day's work makes her worse, and in a few days she is not fit to do her work. The feet become swollen, the arch has visibly yielded in a few days, and the feet are too tender even for light massage.

Another cause is so-called gonorrhœal arthritis affecting the ankle and tarsus. This condition is really a peri-arthritis in which ligaments are infiltrated, soft and easily strained. The patient tries to keep at work and the arch rapidly gives way. A similar state of affairs exists in cases of ' frost bite ' and trench foot, the nutrition of the ligaments is impaired and they rapidly yield. The pain is in proportion to the rapidity with which the ligaments are stretched. Obviously something similar may occur in a limb in which there is a large septic wound, for example in the leg. Again, a simple crush of the foot without any wound or fracture may so strain the ligaments that they rapidly yield to body weight.

The treatment at this stage must be prompt to be effective. First the patient must be put to bed and kept there absolutely ; the foot of the bed should be raised to assist the circulation from the foot ; if the foot itself is too tender to be touched massage of the leg above will help the return circulation and reduce œdema.

As soon as the foot can be handled it should be massaged and the arch moulded up. After a day or two of massage of the foot it can usually be put in plaster well padded with wool and felt and moulded into correct position.

In the ordinary case in civil life after ten days' rest in plaster the patient can usually begin to walk in plaster without pain. The writer found that cases of trench feet seen in 1916–17 which had been under manipulative treatment, baths, faradization, and other treatments, and still remained œdematous and tender after several months, had usually to be kept in bed in plaster for six to eight weeks before they could stand

even in plaster without pain. In these cases each stage of treatment had to be prolonged to three or four times the period required for the treatment of acute flat foot of the corresponding type seen in civil life.

After the plaster is removed the patient is ready for massage and foot movements which must be continued in bed for some days. The

FIG. 156.—Shows the same case as Fig. 155. The right claw foot has been corrected by wrenching and plaster. The left flat foot is still in a walking plaster with the foot inverted.

patient next is allowed up in comfortable boots with the heels crooked, and is given graduated walking exercise ; with soldiers this stage was difficult to control as they would get out once they were allowed on their feet. The further stages are as in type 3, v. *infra.*

2. **Rigid flat foot** occasionally occurs as a congenital defect, but is more often the result of one of the acute conditions just described. The patient has an acute painful flat foot, walks on it till the arch is quite

broken down, then rests till the pain passes off sufficiently to allow him to hobble about again without any attempt to mould the foot into shape. The foot ultimately becomes rigid. The patient treads too much on the inner side of the foot and cannot walk far without the foot beginning to ache. The treatment in these cases must be drastic. The foot must first be made supple by wrenching with a Thomas wrench under an anæsthetic until it is thoroughly flexible in all directions. It should then be immediately put up in layers of cotton-wool bandage and fixed in plaster of Paris with the arch well moulded up and the foot at right angles to the leg and well inverted. There is very little pain after this treatment provided it is thorough. If any adhesions are left unbroken or ligaments left incompletely stretched so that there is still tension on them they will ache unbearably, so that the exhibition of morphia is necessary for two or three days. Usually a small injection after the operation will tide the patient over the first night and then no more will be needed. This treatment really converts a rigid flat foot into an acute one which is immediately treated.

Gunshot wounds and septic infiltration of the foot from septic wounds may give rise to acute and rigid flat foot in the same way.

Even cases where a bullet has traversed the tarsus and comminuted tarsal bones and bases of metatarsals will end up as a serviceable foot in spite of prolonged sepsis if care is taken from the earliest possible stage to keep the foot at right angles to the leg, slightly inverted, and with the arch gently moulded up ; not with the foot bandaged flat down on a flat foot-piece. Even if the sinuses are not closed the patient may get about in plaster of Paris with windows for drainage if the foot is kept steady in good position.

3. **Flexible flat foot** includes the more usual varieties of strain of the mid-tarsal joint, and is the ordinary flat foot seen in practice. Cases vary considerably in degree and in the locality and type of pain of which they complain. All, however, show the defect that the tarsus collapses downwards and inwards when the muscular support is relaxed.

It is still quite a usual thing to find this condition diagnosed as rheumatism, especially if the patient is middle aged. For example, a woman who has been nursing a sick husband or child, when the emergency is over, is tired and run down and complains of aching feet and perhaps aching and fatigue in other joints. In all such cases it is well to see if part of her trouble is wrong balance of the foot, and to relieve this by altering her shoes. At the same time it is proper for the practitioner to remain awake to the fact that there may be some source of septic infection, and that he may have to treat an auto-intoxication from intestine or teeth as well as a mechanical strain. He will earn the gratitude of the patient if he can at once relieve the mechanical strain while the

disinfecting treatment is in progress. In many cases with a septic rheumatoid basis the septic element receives attention while the mechanical strain is allowed to go on often for months, till the patient consults an orthopædic surgeon who may be able mechanically to give her immediate relief. In such cases the patient is apt to have a feeling that the case was not diagnosed properly at first, and it is sometimes difficult to persuade her that the vaccine or other treatment she has received was a very important and necessary part of her cure. One patient's answer was, ' I know I felt better after the treatment, but my feet still ached till I had my shoes altered.'

It is noteworthy that when young children are growing very rapidly, or for any other reason their weight is too much for the ligaments of their insteps, they instinctively turn their toes in when walking. Their parents frequently bring them to see the surgeon, not because they complain of pain, but because they persist in turning their toes in. If the child is left alone standing on his bare feet, and his attention engaged, it will be noticed that as soon as his muscles relax the arch descends. On examination some tenderness is usually elicited by pressure on the inferior calcaneo-scaphoid ligament. The child instinctively inverts his foot to relieve strain on structures below, and to the inner side of the instep.

A treatment for these cases which can be relied on to assist in relaxing the stretched structures and so aid nature to work a cure, is to raise the heel of the boot $\frac{1}{4}$ to $\frac{1}{3}$ of an inch on the inner side and place a small wedge on the sole just behind the head of the first metatarsal. This tilts the foot slightly on the outer edge, and makes the patient turn the toe in slightly when walking.

If this treatment is to be successful it is necessary to explain to the patient in simple words the purpose of the alteration made in the shoes. It must further be impressed on them that they must never for an instant stand bare-footed or in stockinged soles, for a minute of forgetfulness and relaxation of the muscles will let the instep sink, stretching out all the good that has been done during the day. It is therefore essential that all shoes—tennis shoes, house shoes, or slippers—must be altered in the same way. At any time when the patient must be without shoes, for instance getting into or out of a bath, he must do so on tip-toe, for then the muscles take the strain, and the ligaments are kept relaxed.

The patient must be taught to walk with the feet parallel, not with the toes turned out. The reader can demonstrate the object of this on his own feet, first by standing with his feet turned out to nearly 90° from each other, and then leaning forward till the weight comes on the toes. It will be noticed that in this position the weight is nearly all borne on the ball of the great toe, and there is a distinct sense of tension along the inner side of the instep. Second, if he now stand with feet parallel and

again lean forward, he will note that his weight is more evenly distributed on all five toes and that there is less tension on the instep.

It is a great help to teach the patient to walk heel and toe along a straight line, the one footstep coming straight in front of the other: the characteristic footprint of the 'red-skin' described in books of adventure. It may further be noted that successful long-distance runners and pedestrians adopt this gait; they appear to turn their toes in a little, but really only keep their feet parallel. In this way they avoid straining the arch of the foot, they get all five toes to spring from in each stride, and materially lengthen their stride. For those who have not studied barefoot races in the flesh, it is quite worth while to study the gait of 'cannibals' and other savage races shown on the screen at cinematograph entertainments. The untrammelled savage naturally walks with parallel feet.

In cases where the patient soon gets tired and has a considerable amount of pain after standing or walking for a comparatively short time, considerable relief is afforded by strapping the foot with adhesive plaster. If the pain is chiefly across the dorsum of the foot and about the tarsal bones, a firm strap round the instep holding the tarsal bones together will reduce the strain on these joints and will probably afford comfort. In other cases the strap should go round the foot, up the inner side of the foot along the line of the tendon of the tibialis anticus to support the instep, especially if the pain is under the instep. These are to be an adjunct to treatment by slanting the heel of the boot, not an alternative.

It should seldom be necessary to strap the foot for more than a fortnight if the shoe has been properly altered, as by that time patients usually experience considerable relief. In addition to the alteration at the heel, an outside iron extending from below the knee to a socket in the heel of the boot, with a T-strap on the inner side of the boot with which to strap the ankle to the outer bar, is necessary in cases of very weak feet with pronounced valgus deformity at the ankle-joint. This outside brace is a great support, but should be discarded as soon as the patient can do without it. (Fig. 152.)

'Exercises' are often employed for the treatment of flat foot without any clear idea of what is to be accomplished by them. If a patient's foot is so strained that very little ordinary walking makes the foot ache or feel tired, it is obvious that exercises will only add to the fatigue.

It should be impressed on the patient that his feet will recover only if they are kept continually in a position of correct balance, and that this depends partly on his remembering to keep his feet parallel, but chiefly to strict attention to having the boots correctly sloped. He is then told that all exercises must be done with his altered shoes on, otherwise he may let his arch sink too far and stretch his ligaments. He may then

be taught to stand with feet parallel, rise on tip-toe, and sink on to the outer side of the foot. Next he may walk along a straight line to teach him to keep his toes in when walking. These exercises should be done a few times only in the morning—the purpose of the exercise being to remind him of the proper way to walk. Tip-toe exercises by themselves, without instructing the patient how to use his tip-toe movement in walking, often degenerate into a meaningless routine. All shoes for cases of flat foot should be straight on the inner border. Pointed toes abduct the fore part of the foot and prevent the foot from resuming its correct shape when the body weight is deviated to the outer side by altering the heel and wedging up the inner side of the sole.

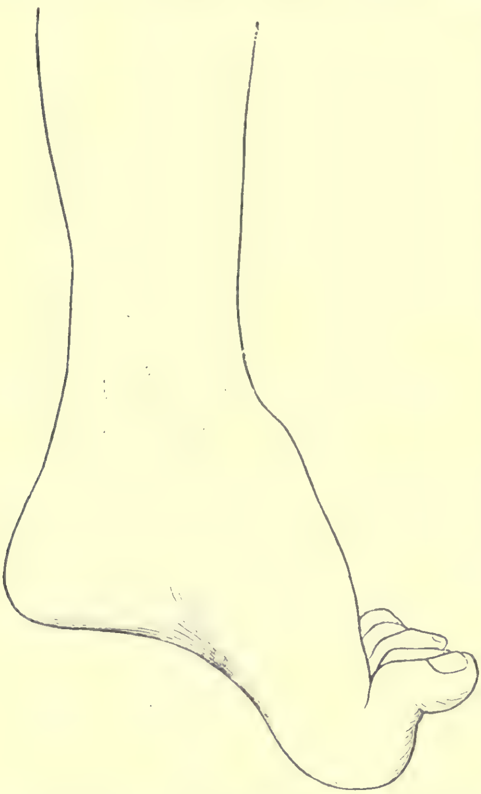


FIG. 157. An outline drawing from a cast showing the characteristic features of 'claw foot'.

Claw foot, pes cavus or pes arcuatus, is a deformity the opposite of flat foot. In this condition the foot is flexed and often a little adducted at the mid-tarsal joint ; along with this the toes are hyperextended at the metatarso-phalangeal joints and flexed at the interphalangeal joints. The foot thus presents an exaggeration of the hollow of the instep and a very prominent ball of the foot. (Fig. 157.)

An 'idiopathic' form of this condition is frequently met with in civil practice. In these cases it is difficult to find any definite cause, though some transitory paralytic condition is suspected. Sometimes it is possible to get a definite history of a slight attack of poliomyelitis. A deformity of exactly the same appearance occurs in some of the progressive palsies. It may arise as a sequel to trench foot and is then probably the result of the decubitus during the stage when the patient was in bed. Finally, it may arise in cases of wounds of the foot or of the lower limb, as the result of contracture of scars or as the sequel of sepsis. The common factor to be found in all cases is that for a time there has been a disturbance

of balance between the flexors and extensors of the mid-tarsal joint, and subsequently the muscles, fasciæ, and ligaments in the concavity of the foot have become short and contracted. The contracture of the extensors of the toes seems to be secondary, and due to an effort on the part of these muscles to reinforce extensors of the foot at the mid-tarsal joint.

The disability is that the patient cannot get his heel properly to the ground, carries all the weight on the heads of the metatarsals, and consequently gets painful callosities on the ball of the foot under the heads of the metatarsals. It is the pain of these callosities which often is the immediate cause of the patient consulting a surgeon.

The defect is once more an improper balance of the foot, and this is to be corrected by straightening out the foot at the mid-tarsal joint first, fully flexing the toes and then stretching or elongating the tendo Achillis, and finally making the patient walk with the heel down and the fore part of the foot dorsiflexed. The tendo Achillis is rarely short in these cases, but often has to be stretched because it is not possible to correct the cavus of the foot sufficiently to secure comfort.

Treatment. Mild degrees of the deformity consist merely of tightness of the tendo Achillis keeping the foot from being dorsiflexed beyond a right angle, associated with commencing tightness of the structures in the sole. If recognized at this stage passive stretching of the tight structures followed by the wearing of low-heeled shoes with a bar $\frac{1}{2}$ in. thick across the sole to compel dorsiflexion is sometimes sufficient, especially in children.

The condition is not usually recognized till it has reached the second or third stage. These two stages look very much alike as the typical cavus and dorsiflexion of the toes is present, but may be distinguished by the fact that if the surgeon places his finger under the ball of the foot and dorsiflexes the ankle the extensors relax and the toes straighten in the second stage; but in the third stage the toes remain dorsiflexed owing to the greater contracture of the extensor muscles.

Treatment consists in subcutaneous division of all tense bands in the sole and then wrenching the foot till the sole is quite flat. If necessary, the tight extensors of the toes are then divided and the toes fully flexed. Finally, after the deformity of the foot is fully corrected, the tendo Achillis may be elongated to correct the equinus deformity at the ankle, and the extensor proprius hallucis inserted into the neck of the first metatarsal to act as an additional extensor of the mid-tarsal joint.

After-treatment is almost more important than the operative stage, for many cases are allowed to relapse from inefficient, or at any rat ineffective, after-treatment. While the patient is under the anæsthetic the foot must be fixed in fully corrected position. This is most effectively done in plaster. A felt pad, two fingers' breadth in width and $\frac{3}{4}$ in. thick,

is placed across the sole just behind the heads of the metatarsals and a flat sole-piece of metal or wood placed on the sole and enclosed in the plaster. Another pad of felt is placed across the toes and they are flexed over the pad on the sole. Care must be taken that the ankle is dorsiflexed, the sole flat, the toes flexed, and that no pressure sores are produced either on the dorsum of the foot or on the ball of the foot.

If the foot has been at all difficult to wrench it will be at least a week or ten days before the patient will care to put his foot to the ground even in plaster. After that he should walk in plaster for three or four weeks, and then wear low heels and a bar on the sole of his boot for three or four months. Any less rigorous course of treatment is likely to fail, for unless it is thoroughly corrected the condition is apt to recur, and even with this course of after-treatment it is sometimes necessary to wrench the foot a second time.

Neglected cases of claw foot in course of years may become very severely deformed, reaching the fourth and fifth stages described by Sir Robert Jones. These cases are not likely to find their way into the army, and therefore need not be dealt with in detail here.

THE FORE PART OF THE FOOT

The fore part of the foot consists of all the foot in front of the mid-tarsal joint. It forms the anterior part of the longitudinal arch, and by its breadth gives the foot the power of balancing laterally.

The noteworthy architectural feature of the fore part of the foot is that it is arched laterally. This lateral arch is known as the transverse arch of the foot. It appears at the posterior end of the fore part of the foot in the three cuneiform bones and the cuboid. This part of the arch rests on the cuboid on the outer side, but is broken on the inner side ; it requires the corresponding part of the other foot to complete the whole arch in this part of the dome formed by the two feet when placed side by side.

Anteriorly the transverse arch of the foot is supported at both ends on the head of the first metatarsal on the inner side, and the head of the fifth metatarsal on the outer side. The intervening portion formed by the intermediate metatarsal heads is freely mobile and not firmly locked together as at the line of the cuneiform bones and the bases of the metatarsals. The lateral balance of the foot depends in large measure on the control of this arch by the small muscles of the foot. If these muscles are wasted from disuse as in people who wear narrow-toed boots, the front part of the transverse arch is weak, as is shown by the way in which the fore part of the foot flattens out when they stand barefoot. A proper working boot should be so broad on the sole that the fore part of the foot

can spread and contract in the boot according as the weight to be carried is greater or less.

Many people wear shoes of which the sole is narrower than the distance between the heads of the first and fifth metatarsals, so that the outer and inner margins of the foot are crowded up off the sole of the boot into the sides of the uppers. The result is that the middle three metatarsal heads fall down in the middle of the arch.

A collapsed transverse arch is often associated with a weak foot and collapse of the longitudinal arch. Beyond the weakness of the foot, often only discovered when the patient undertakes more work than usual, transverse flat foot does not itself inconvenience the patient much unless it is associated with either metatarsalgia or corns on the sole.

METATARSALGIA

Metatarsal neuralgia, or Morton's disease, was described by Morton in 1886 as neuralgia due to compression of digital nerves between the heads of metatarsals. Robert Jones investigated the condition independently in 1892 and found that the sudden severe neuralgic pain characteristic of the condition is due to compression of nerve twigs by metatarsal heads which have fallen down out of their proper position in the transverse arch, and in this way nip the nerves between the head of the metatarsal bone and the ground.

Symptoms and Diagnosis. The patient complains of pain like a 'hot pea' or a nail in one metatarsal-phalangeal joint, usually the fourth, often the third, and rarely the second; the pain comes on at any time when walking, sometimes when at rest. Some patients find that they have to stop and take the shoe off because the pain is so intense, some find that they can relieve the pain by grasping the foot round the metatarsals—this helps to restore the transverse arch. In more severe cases the pain is continuous, radiates into the toe and up the leg, and trophic changes appear in the nail and the appearance of the skin of the toe, apparently due to interference with the nerve supply. Pain may be so great that the patient cannot walk at all. The diagnosis is confirmed by pinching the metatarso-phalangeal joints in succession, when the one at fault will be found to be tender. If two or more joints are found to be tender, the one which is most acutely tender is the real offender.

Treatment consists in relieving the nerve from the pressure of the descended metatarsal head. A simple and easy way of doing this is by putting a leather bar across the sole of the boot, $\frac{1}{2}$ in. thick and $\frac{3}{4}$ in. broad, placed behind the heads of the metatarsals. As the patient walks, the sole in front of the bar becomes depressed, making a countersunk hollow in the sole, so the pressure on the heads of the metatarsals is relieved.

This shaping of the sole of the boot is accelerated if the patient lets the boots get wet and walks in them while the soles are wet. In some cases a felt pad placed inside the boot just behind the offending metatarsal head gives great relief.

A good shoemaker can make the bar more elegant, or localize it more behind the particular toe which is offending, but these refinements of the plain bar are often not so satisfactory and are much more expensive. Further relief can often be given by fixing a band of adhesive strapping round the foot in the region of the proximal half of the metatarsus so as to support the transverse arch.

In severe cases, especially those with trophic changes in the toe, there is no relief to be obtained except by operation. The object of treatment being to relieve pressure on the nerve by the metatarsal head, the obvious operation is to excise the offending head.

Operation. A longitudinal incision along the side of the extensor tendon. Open the metatarso-phalangeal joint, free the head from the capsule, turn it out of the joint and nip through the neck of the metatarsal with bone-cutters. Stitch the wound. When bandaging place a pad of wool in the sole so as to remodel the transverse arch. In about three weeks the patient may get up with a bar on the sole of the boot behind the line of the heads of the metatarsals.

HALLUX VALGUS, HALLUX RIGIDUS, HALLUX FLEXUS,

are terms which describe different phases of disturbance of balance of the great toe-joint which is often, one might say usually, associated with some perceptible degree of flattening of either the longitudinal or transverse arches of the foot, or of both.

The position of the head of the first metatarsal and of the great toe plays an important part in the mechanical balance of the fore part of the foot. In the foot of the young child and of people who have always gone barefoot, the first metatarsal and the great toe are in the line of the neck of the astragalus directed downwards, forwards, and slightly inwards towards the middle line of the body. If the foot is carrying weight the great toe spreads still further towards the middle line, thus broadening the base of support of the foot as a whole, i. e. it widens the distance between the heads of the first and fifth metatarsals which, with the tip of the os calcis, form the triangle on which the arches of the foot rest. Another very important mechanical effect of this spreading of the great toe towards the middle line of the body is that in this position the first metatarsal forms a better prop for the longitudinal arch, preventing it from capsizing to the inner side.

Thus freedom of the fore part of the foot to spread and contract laterally not only helps in maintaining the transverse arch by exercising the small muscles of the foot which control it, but the spreading of the great toe inwards is an important factor in maintaining the longitudinal arch, especially when an extra load is being carried, as when a man is carrying a pack. Boots commonly worn do not allow this freedom of movement.

In the first place, boots are commonly designed with a more or less pointed toe. When a pair of boots are placed side by side the inner borders should be parallel as far as the end of the great toe. This is nearly achieved in the so-called American shapes, but in the usual English shapes the toes are crowded together, preventing the proper use of the fore part in balancing and leading to atrophy of its muscles from disuse. The second fault is that in order to have the boot look small and neat the soles are made too narrow for the tread of the ball of the foot; the shoemaker makes up for this by making more room in the upper; consequently, when the foot is put into the boot the head of the first metatarsal and the head of the fifth are overhanging the sole in bulging pockets of the upper. In this position the transverse arch cannot rest properly on the two ends and the middle of the arch collapses, and metatarsalgic pains may follow. Turning next to the first metatarsal and toe, it is to be noted that in this type of boot the great toe is pushed into a valgus position and the first metatarsal and great toe cannot spread inward to prop the longitudinal arch. When the patient feels his arch collapsing inwards he makes an instinctive muscular effort to press his great toe downwards and inwards, thus undue pressure and strain is brought to bear on the great toe-joint.

It is difficult to classify the types of cases properly, but given the disturbing factors of badly designed boots, plus some extra strain, such as an unusual amount of standing or walking, either the arch will collapse or the first metatarsal joint become tender from overstrain. The writer thinks that the patient with a naturally high arch is likely to complain first of trouble in the arch, while a patient with a naturally low arch is not so likely to complain early of strain and pain in the instep, and therefore is able to keep going for a longer time and only comes for advice when he gets pain in the great toe-joint from strain. This is, however, only a general impression, and the writer cannot confirm it by statistics.

The point to be grasped is that in the metatarso-phalangeal joint proper balance is essential to efficient function. Therefore, when proper balance is not maintained, undue strain occurs, giving rise (*a*) to slow adaptive changes such as are seen in cases of hallux valgus which have been slowly progressing over a long period of years with corresponding changes

in the joint surfaces, but without painful arthritis ; (*b*) if the joint is more rapidly strained then inflammatory reactions occur : (1) strain of ligaments, pain, and effusion into the joint. (2) Osteo-arthritic changes with osteophytic outgrowths of bone along the edges of the joint. These are the natural reactions to repeated strains and small injuries. (3) An adventitious bursa over bony prominences known as a bunion.

Movements of the joint may therefore be free in some directions and limited in others by bony excrescences. If there has been much arthritis the joint may become quite stiff as in cases of true hallux rigidus. Similar conditions may obviously arise from direct trauma such as 'stubbing' the toe at football, or by a crush, as when a horse steps on the toe. Wounds or sepsis may give rise to stiffness or ankylosis, which is to be treated on similar lines to those about to be described.

Treatment. In early cases of pain in the great toe-joint, a diagnosis may be confirmed by eliciting tenderness by compressing the joint between the finger and thumb, from above downwards and inwards. At this stage there may be no obvious limitation to movement in quiescent stages, but some limitation when the joint is tender and swollen after exercise.

The treatment is obviously to relieve the joint from pressure and strain. This is conveniently done by putting a wedge on the sole of the boot, $\frac{1}{2}$ of an inch thick and $\frac{3}{4}$ of an inch wide behind the head of the metatarsal. The boot should be an ordinary walking boot. When the patient walks in the boot, the head of the metatarsal makes a hollow for itself in front of the wedge, and then the weight of the body falls on the neck of the metatarsal which rests on the wedge. In this way the tender joint is rested and generally recovers. Relief of pressure is further secured by 'crooking' the heel (i. e. raising it $\frac{1}{3}$ of an inch on the inner side), so as to deviate the body weight on to the outer side of the foot.

In more advanced cases there is limitation of movement and deformity of the bone ends. Hallux valgus is the name given when the great toe is deviated to the outer side against the second toe, while in severe cases of deformity it may lie over or under the second toe. It is to be noted that patients seldom complain of the deformed position of the toe unless there is either a tender bursa over the prominent metatarsal head or pain from osteo-arthritic changes in the joint. In very early cases in children it may be possible to strap the toe straight with adhesive plaster provided there are no changes in the joint surfaces ; in adults this is rarely effective.

Operation to remove the bursa is of little use unless an operation is also performed to straighten the toe, for there will still be friction by the boot on the prominent knuckle of bone. The method of operation depends on the X-ray appearances of the edge of the joint and on the appearance of the bone when exposed at the operation.

(*a*) If there are no osteophytic outgrowths and the joint itself is mobile, it will suffice to divide the extensor tendons of the great toe subcutaneously and perform a cuneiform osteotomy of the neck of the metatarsal. The toe can then be straightened and fixed on an internal hallux valgus splint, which is a gutter splint of sheet metal with a hole in it opposite the position of the head of the metatarsal.

(*b*) If there is an osteophytic outgrowth on the inner aspect of the head only but the joint surface is otherwise good, it is necessary to remove the projecting bone. Expose the whole inner side of the joint by reflecting a flap of skin and superficial fascia. Next turn back a flap base towards the heel—the flap should consist of the inner part of the capsule and periosteum—thus opening the joint and exposing bare bone on the inner side of the head of the metatarsal. The bursa, if present, is contained in this flap.

If the pink irregular osteophytic bone is very limited in area, remove a wedge entering the osteotome close to healthy cartilage in front and behind the osteophyte, but do not divide the attachments of the head to soft parts on the outer side. Then taking hold of the toe forcibly adduct the head of the metatarsal and great toe. The deformity being thus corrected, remove the outer wall of the bursa and use the flap of deep tissue to make a good internal ligament, suture the skin and fix in a splint or in plaster of Paris in corrected position. The operation should be planned so as to leave the periosteum intact on the outer side.

If during this operation the osteotome slips, or the head of the metatarsal gets broken right off and is detached from all its blood supply, remove it and finish the operation as in the following operation.

(*c*) If there is much osteo-arthritic change in the bone and not a good joint surface, expose as in the former operation, turning back a deep flap containing the bursa in the same way. Next remove the whole head and at least ½ an inch of the neck of the metatarsal. The deep flap is then turned in to cover the cut end of the bone. Mayo advocates using the whole bursa for this. Robert Jones reports that in one case there was trouble afterwards from bursitis in the reflected bursa, and therefore advocates that only one wall of the bursa be used to cover the bone. If the deep flap is thick and contains a good bursa it is sometimes possible to split it into two layers ; the deep layer is then turned in to cover the bone, while the superficial layer is used to close the new joint by stitching it to the side of the phalanx, thus making an internal ligament or capsule.

The patient may be allowed up in plaster three weeks after the operation with a felt pad in the sole behind the joint, so as to avoid direct pressure on the joint. A fortnight later he may walk in a boot with a good wedge on the sole behind the new joint.

Hallux rigidus or hallux flexus is a deformity in which there is limitation of dorsiflexion of the first metatarso-phalangeal joint. The patient cannot walk in comfort because he cannot step off the foot directly forward on account of the limitation in dorsiflexion. As in the former condition the trouble may be (1) tenderness and slight limitation of movement without gross changes in the edges of the joint, in which case forcibly dorsiflexing the joint and fixing it in that position in plaster of Paris for ten days or a fortnight may suffice to restore freedom of movement. The patient afterwards wears a wedge bar behind the joint for several weeks till he has learned to walk with comfort, and all tenderness and pain has subsided. (2) There may be osteophytic outgrowths on the dorsum of the metatarsal head, in which case a limited wedge osteotomy base upwards, as in the second operation described above, will suffice. Sometimes the upper lip of the phalanx should also be removed if it projects too much. (3) If the osteo-arthritis is extensive or the joint ankylosed, a frank excision of the head and the formation of a false joint as described above is the only useful procedure.

It is wise at once to fix the foot in plaster with the toe dorsiflexed in these cases. If for any reason the operation is not successful and the joint is again ankylosed the toe will be more out of the way in walking if it is set slightly dorsiflexed. The after-treatment is with a bar or wedge behind the joint as before.

HAMMER TOE

This condition usually affects the second toe, rarely the third or fourth. It is often associated with hallux valgus.

The deformity consists in dorsiflexion of the metatarso-phalangeal joint and flexion of the interphalangeal joints.

The treatment is to straighten the toe, never to amputate, because if the second toe is amputated the great toe has nothing to steady it on the outer side and hallux valgus often follows.

(1) In children manipulation and strapping the toe straight with adhesive plaster is sometimes effective.

(2) In slightly more advanced cases, it is necessary first to divide the extensor and flexor tendons and the capsule on the flexor aspect of the proximal interphalangeal joint, and then fix the toe on a very small splint with strapping.

(3) The radical operation is to perform the tenotomies just mentioned and also excise the proximal interphalangeal joint.

The Operation. A lozenge-shaped piece of skin is excised over the prominent proximal interphalangeal joint. The head of the proximal phalanx and the base of the second phalanx are nipped off. The skin is

then sutured so as to make a transverse wound ; this straightens the toe. No local splint is necessary as a rule, but the foot should be put in a right-angled shoe-splint to keep it steady. The object of the operation is to produce ankylosis of the interphalangeal joint. If a false joint form the condition is apt to recur.

Deviated fifth toe is a condition in which the little toe is adducted over the dorsum of the foot. The condition is usually congenital and often hereditary. The only trouble which it gives is from difficulty in getting comfortable boots, with consequent pressure and corns. In young infants persistent manipulation and daily application of adhesive strapping to pull the toe into proper line is often successful. In adults amputation is the simplest treatment, leaving the head of the metatarsal untouched.

ANKYLOSIS AND STIFF JOINTS

A Consideration in Relation to Deformity

BY

SIR ROBERT JONES

ANKYLOSIS AND STIFF JOINTS

STIFF AND ANKYLOSED JOINTS

In dealing with this subject I wish to confine my remarks to the later treatment to which it is necessary to subject joints injured in war.

In the early phases of the campaign most compound injuries were followed by sepsis, generally of a virulent type, and hardly a single wound escaped complications.

Improved and more rapid transport and early and thorough excision of wounds, together with the physiological treatment applied to them later, wrought a most needed improvement in results. The cases, therefore, which reached our shores in the early stages of the war were in a much worse condition than the later cases, both as regards malposition and destruction of joints. In injuries of joints if amputation was averted, ankylosis was the best to be hoped for, and the first two years of the war have supplied us with so large a number of joints stiff or ankylosed in malposition as will keep the surgeon active for several years.

I will deal first with the milder type of stiffness, the result of injuries other than direct gunshot wounds.

STIFF JOINTS OF A MILD TYPE NOT THE RESULT OF SEPSIS

These will include :

Sprains of joints involving muscular attachments and ligaments.
Stiffness following dislocations.
Stiffness following prolonged immobilization.
Contusion of joint cartilages.

Joints are often limited in movement from the action of structures about them without appreciable injury to bone or cartilage.

This can be illustrated by the so-called sprain of the ankle. In traversing rough ground the soldier suddenly twists his foot inwards, deviating the whole of his body-weight upon the structures on the outer side of the ankle. He continues to hobble for a while, until, when the surgeon sees him, the joint is badly swollen. A diagnosis is made of strained or ruptured external lateral ligament. This diagnosis is arrived at by the pain experienced on pressure over the ligament, especially over its bony attachments, and pain over the ligament on inversion of the foot.

The essential principle of treatment is to keep the torn structure relaxed—which is effected by fixing the foot in eversion. This fixation in the initial stage is of infinitely greater value than any type of physiotherapy. It brings about union of the torn structures by immediate rather than by delayed union. Infusion of blood is obstructed by firm bandaging over cotton-wool ; massage can be started in a few days and later movements of a passive and an active type, so planned that no strain should be thrown upon the ruptured ligament.

When the patient is first allowed to walk his boot should be so altered in the heel and outer edge of the sole that the body-weight is deflected from the outer side during walking. If treated in this way, complete and prompt recovery will take place. If, however, the ankle is immediately subjected to manipulation and massage, complicated by hydrotherapy without reference to the anatomical lesion, recovery is distinctly retarded.

Worse still is the method of immobilization for weeks in plaster, which indefinitely perpetuates weakness and disability. A badly sprained ankle treated with deference to anatomical lesions should make a complete recovery in fourteen days.

These principles laid down in the case of the ankle obtain in the case of all other joints, i.e.

(*a*) Keep torn ligaments relaxed to encourage immediate union.
(*b*) Obstruct effusion of blood and serum by firm pressure.
(*c*) Delay manipulation for a few days and avoid any movement which stretches the torn structure.
(*d*) Protect the torn structure from the strain of body-weight.
(*e*) Encourage the earliest function with the above reservations.

The same procedure and line of thought must govern us when dealing with ruptured muscle in any part of its length or at its attachments about the joint.

I will illustrate this by the so-called injury ‘ rupture of the plantaris ’, which is generally a tear of muscular fibre in gastrocnemius or soleus.

The precise painful spot is located and a pad is placed over it. The foot is held slightly more flexed than at a right angle, and from the malleoli upwards the calf is supported by layers of sticking plaster ending just below the knee. Three-quarters of an inch is added to the height of the heel and immediate walking is permitted. In two or three days the patient can walk painlessly and with barely a limp, function and physiological rest being happily combined. The same condition treated by immediate massage and movement would be much less effectively corrected and would take much more time for recovery. The treatment of the more chronic type of these conditions of strain will be dealt with later.

EXTENSIVE RUPTURE OF LIGAMENTS DUE TO DISLOCATION

Here obviously reduction of the displacement is the first consideration, and this must be followed by sufficient rest to allow of repair of the injured tissues.

Repair is accompanied by a deposit of fibrous tissue following an effusion of blood and serum which it is necessary to keep in check, otherwise strong bands of fibrous tissue form, which impede free motion in a joint and which may require breaking down at a later stage. As a rule we may conclude that any simple dislocation of a joint which at a later stage requires the formal breaking down of adhesions which have formed around it, has not experienced efficient initial treatment. It is necessary from the first to give rest to the injured tissues only until such time that one can with safety, and by a graduated scheme, prevent obstructive bands from maturing. As an instance I will take the case of a posterior dislocation of an adult elbow, complicated or not by a fracture of the coronoid. After the reduction, the arm is kept acutely flexed. This relieves the torn structures at the front of the joint and maintains the elbow at rest. In four or five days, if left alone, pain on pressure over the front of the elbow will have gone. This tenderness to pressure is an important index, for it denotes that the cicatrix is still so fresh and vascular that any attempt at passive extension will supply those factors of irritation which make for firm fibrous adhesions. When tenderness on pressure has gone, massage will assist absorption, and graduated extension of the elbow may be begun.

This should at first be done entirely by the patient. The sling is so slackened that the elbow may be allowed to extend by about 20°, and voluntary movement within that radius can be advised. When these movements are painless and easy the sling can be relaxed still further from day to day. In about fourteen days passive movement can be started. The joint should be very gently moved through its complete range, and then rested until it recovers from the assault. The object is to stretch the adhesions so gently as to minimize reaction. The movements of flexion, supination, pronation, and extension should be performed once only.

The to and fro, oft-repeated method should be condemned. Fractures into joints are treated in accordance with the same principle, care being taken to prevent callus exudation from being obstructive. We must never add the injury caused by passive movement to an existing active state of reparative inflammation, but wait until the reparative action has sufficiently advanced.

If the patient's range of voluntary movement the day after passive movement is less than before, it is a clear indication that the joint is still

too actively inflamed to undergo the process. If after passive movement the pain is *not* increased and the range of movement is greater than before, it is safe to go on with both active and passive movement.

PROLONGED IMMOBILIZATION

This subject will be dealt with when considering individual joints, but it may be stated that by utilizing the knowledge we possess we can nearly always avoid the stiffening of joints which has so frequently followed fractures of the long bones. This is especially the case where we have been dealing with simple fractures. Nothing has been more distressing than to meet a multitude of stiff joints which often require months of treatment where a little care and forethought would have preserved their full function. This has been especially noted in the shoulder, wrist, fingers, knee, and ankle.

CONTUSION OF JOINT CARTILAGE

This condition is met with most often in the shoulder and sometimes in the knee.

It produces pain and stiffness and is one of those conditions where early passive movements are often harmful.

In the shoulder it is apt to follow falls on the hand such as those which result in a Colles's fracture. No complaint is made until a fortnight or three weeks have passed and the patient commences to use his arm. Pain is the early symptom, followed closely by stiffness. Movement increases the pain and there is an increasing limitation of motion. A crushing or bruising of the cartilage of the shoulder-joint is the cause of these symptoms. The impetus of the fall upon the hand has been met by a concussion of the surfaces of the shoulder-joint. The pathology is not very clear, but when we remember that cartilage is non-vascular it deals with the effect of injury very much as does the cornea. When the cornea is injured, no repair can take place till a leash of new vessels grows in from the nearest point of the sclerotic. When repair is complete these vessels disappear, leaving but the slightest trace leading to the nebula, which is the cicatrix.

It is reasonable to suspect from its clinical behaviour that a similar process occurs in injured cartilage. The débris of crushed cells and cartilaginous tissue cannot be cleared away till vascularization occurs in the form of reparative inflammation.

In the case of the shoulder this process starts painlessly while the arm is kept still, and in about a fortnight or so the vascularization is active and the effect of movement is to add to the injury, the stiffness, and the pain.

This condition should be treated by rest for at least three weeks, and then the joint should gradually be taken through its range of movement.

ON THE BREAKING DOWN OF PERI-ARTICULAR ADHESIONS

Stiffness due to adhesions of the lighter type have often to be broken down, and the question will arise ' How are we to diagnose those conditions improved by manipulation and those harmed by it ? '

To assist in this diagnosis I will formulate certain rules which may help the surgeon.

(*a*) Pain on movement in every direction suggests a lesion in the joint or in parts intimately connected with it.

(*b*) Freedom of movement in one or more directions, but not in all, suggests a lesion of some groups of structures outside the joint proper.

(*c*) A joint may be assumed to be free from arthritis when even one of its movements is free.

(*d*) Traumatic arthritis follows an injury after an interval of free movement lasting usually over several days.

(*e*) Restricted movements due to adhesions arise very shortly after the occurrence of injury.

(*f*) Except when following serious injuries, adhesions restrict the movements of joints in one or more but not in all directions.

A joint the seat of arthritis should not be moved until all inflammatory symptoms have subsided.

On passive movements a joint with fibrous adhesions conveys a characteristic sensation to the hands of the surgeon which differs on the one hand from muscular resistance associated with pain, and the abrupt blocking of movement caused by a bony obstruction on the other.

The cessation of movement is definite and unmistakable, but it is not associated with pain unless the surgeon exerts a little force to put tension on the fibrous bands. If in any doubt whether there is disease of the osseous elements of the joint, an X-ray photograph will dissipate it.

ON THE BREAKING DOWN OF ADHESIONS

I want it to be clearly understood that we are dealing here with the simpler forms of peri-articular adhesions—not those accompanied by destruction of joint surfaces, nor those where septic processes have involved the structures round the joint. These severe cases should be approached in quite another way and are not suitable for so-called forcible manipulation.

Many tragedies have already occurred by not grasping this fact. It is fundamental and arresting.

To give emphasis to this I submit the following rules :

1. Before breaking down adhesions exclude the presence of active arthritis.
2. In breaking down adhesions in stiffness following traumatic

arthritis we must proceed very slowly, and if inflammatory reaction supervenes the manipulation should not be repeated.

3. Joints stiff following septic conditions within or immediately without the joint should not be submitted to forcible manipulation.
4. Adhesions are best broken down under complete anæsthesia and the joint should be put through its complete range of movement, otherwise a recurrence of stiffness may be expected.
5. Sudden jerking movements must be avoided because (*a*) they are inefficient, (*b*) they cause unnecessary trauma, (*c*) they may break a bone instead of a fibrous band.

We will next consider the indications for breaking down adhesions and separate this group from that in which the stiffness will recover without intervention. This may be done by formulating rules.

(*a*) Stiffness which gradually disappears as the joint is used may be safely left alone.
(*b*) The increase of the range of movement must be in every direction.
(*c*) If the increase of the range of movement in all directions, or any one direction, ceases to progress, intervention is called for.

Other factors being equal, a young joint will less often require manipulation than that in older folk. Prolonged immobilization of a joint in young people will usually recover by voluntary effort and physio-therapy. Prolonged immobilization in older folk has more serious results. The technique of breaking down adhesions and the principles that govern it are similar in all joints, and I will confine myself to describing the procedures in the case of the shoulder and of the knee.

In the case of the *shoulder* a comparison should be made between the range of movement on both sides, as very considerable variations are met with in different people.

The dangers of this operation in the elderly soldier are, fracture through the surgical neck and, more rarely, dislocation.

The patient is placed on his back with his shoulder protruding over the side of the table and, in order to avoid excessive strain on the upper part of the humerus, the assistant places his fist in the axilla. The arm is then slowly abducted until the normal range—always compared with the opposite shoulder—is reached. With the arm completely abducted the elbow should be flexed, and inward and outward rotation of the humerus gently yet firmly and thoroughly performed. This is the movement associated with fracture of the neck in the older subject. With the arm abducted and the hand behind the head, the flexed elbow should be pressed downwards below the level of the head. The final movement should be circumduction in an ever-increasing circle. The

scapula is now released and put through its range of separate movement for fear adhesions have formed limiting its freedom also. While the patient recovers from the anæsthetic and until he is able to perform his exercises, the arm should be kept abducted. As soon as he is conscious he should voluntarily perform the full shoulder movements aided by the surgeon or nurse. The movements for the first few days are always painful, and here physio-therapy represented by massage and hot bathing soothes and comforts.

In the case of the knee it must be borne in mind that flexion and extension are not its only movements, but that rotatory movements should be practised from every angle. It is these rotatory movements which are so successful where symptoms resembling internal derangements occur.

Finger-joints require some modification of these movements and will be referred to when dealing with the hand.

Certain symptoms following manipulation and passive movements indicating injurious strain may be here formulated.

(*a*) If pain occurs after manipulation and is of *short* duration—the movements may be safely continued.

(*b*) If pain persists for lengthy periods after manipulation—rest is indicated.

(*c*) If the increased range of movement is maintained after manipulation—further movements can be safely prescribed.

(*d*) If in spite of movements, even in the absence of great pain, the range is continuously diminishing—rest is indicated.

(*e*) The duration of pain when tissues are relaxed, rather than its intensity, should be our clinical guide.

(*f*) In breaking down adhesions and in subsequent manipulations, the joint should be put through its various movements only once. The oft-repeated pump-handle movements applied at each sitting are never useful and often start inflammatory symptoms.

(*g*) Unlimited voluntary movements can be safely allowed and should always be encouraged. They are not followed by obstructive reaction.

STIFF JOINTS DUE TO BONY OBSTRUCTION

A bony block to movement in a joint is easily distinguished from other conditions. Movement within a given range is usually free and easy until the block intervenes with a sensation of finality. The elbow and ankle are the joints most commonly affected. A stereoscopic X-ray will portray the limitation of the obstruction.

The conditions which give rise to this disability are :

Myositis ossificans ;
A projecting end of bone ;
Excessive callus exudation ;
Unreduced dislocation.

Although myositis is not a condition specially connected with war wounds, I have seen many instances of it, nearly always in connexion with the elbow-joint. It may be looked upon always as a serious menace to the free action of the joint and by no means easy to overcome. It is generally associated with dislocation of the elbow accompanied by fracture of the coronoid. It is more common in the very young than in older folk and grows more rapidly in children. It is doubtless associated with an escape of bone elements induced by the original trauma. The original injury results in considerable tearing of muscular attachment from bone, accompanied by a varying amount of hæmorrhage. With the torn muscular attachments fragments of periosteum and osteogenetic tissue are pulled away, and it is probably these which are the originators of the formation of new bone along the interfibrillary and intermuscular septa. We cannot prevent the detachment of osteoblastic tissue from forming bone, but we can limit its activities by restraining our own. Although the new bone does not necessarily correspond to a muscle area it is more commonly found in relation to the biceps and brachialis anticus than elsewhere. Certain facts of practical importance regarding this condition can be formulated.

(*a*) Massage favours the development of the osteophytes.
(*b*) In children it is associated with excessive passive movement.
(*c*) Rest in the early stage is indicated.
(*d*) Operation if decided upon should never be undertaken in the early stage of development—for recurrence will take place.
(*e*) Operation should be performed only when the bone is dense and its growth ended.

Operation is only likely to prove of benefit when the attack is reserved for a bony buttress which can be quite completely removed. Even then the result is often disappointing. Projecting fragments of bone, old unreduced dislocations and excessive callus exudations will be discussed when we deal with individual joints.

STIFFNESS DUE TO THE CONTRACTION OF SCAR TISSUE

The war has supplied us with numerous instances of joints fixed in deformities due to the contraction of scar tissue. This most frequently happens in the shoulder, elbow, wrist, hand, and knee. The malposition

can be avoided by correct initial treatment whatever the extent of the destructive process, and as the matter is a very important one, I purpose discussing the histological changes and how they can be controlled in order to prevent stiffness of joints and mechanical disabilities due to contracting scars.

My colleague, McCrae Aitken, has paid special attention to this subject, and I am drawing largely upon his experiences and am able to fully confirm his views from the clinical side.

(*a*) The early processes of repair in all tissues include the removal of dead tissues, sloughs, and necroses, and the establishment of an active hyperæmia with the formation of new loops of blood-vessels permeating the mass of blood-clot, exudate, and damaged tissues. In a surface wound this includes all stages up to the establishment of granulation tissue.

(*b*) The second stage is that of immature formed repair elements, especially the laying down of fibrous tissue and bone elements to form cicatrix and callus. In this stage the seat of injury is still hyperæmic, but as the formed elements mature the vascularity gradually diminishes and the whole seat of repair passes gradually into the third stage.

(*c*) The mature scar consists of fully-formed fibrous tissue elements and hard callus. The fibrous tissue has become white owing to the disappearance of active hyperæmia, and in other cases, owing to contraction of fibrous tissue, repair of other parts of the wound is impeded for want of blood.

When the scar is situated in such places as the front of the wrist, the back of the knee, the flexure of the elbow, &c., there is a great tendency for the scar to go on contracting till the limb is fixed in a useless flexed position. Owing to the contraction of the scar the blood-vessels cannot expand freely, and the whole area becomes dense, white, and anæmic.

In the **first stage** the region of the wound must be left very much at rest. Fractures should be placed in the best position, torn tissues brought together as well as possible, and then left for the new repair blood-vessels to grow between fragments. These vessels grow in the plastic exudate, therefore any rough handling, injudicious massage, or movement will only tear them and obstruct healing. The wound must be treated on modern lines ; free exit given to all discharges in septic cases so that the tissues may be as little sodden in poisonous toxins as possible and be freely nourished and fortified by the food elements and antibodies in the blood fluids.

This is the stage in which the surgeon must decide as to the position in which he requires to place the limb. It should be placed in the position

opposed to the direction in which the scar contracts. The limb should retain this position until repair is well established.

In the second stage passive movement is apt to tear newly formed tissues, cause bleeding and increased organization of scar tissue. On the other hand it is now possible to gradually change the position of the limb. It is during the end of this stage, when the tissues are becoming matured, that the contractile element is at work ; therefore if the limb has not already been put up in the position opposed to deformity it should be done as soon as possible.

The following rules should be observed :

1. The strong muscles in the axillary fold when torn by shrapnel must not be allowed to heal with a short stiff scar ; therefore the arm should be abducted.
2. Wounds in the flexure of the elbow should be treated with the elbow extended.
3. Burns and septic wounds of the front of the wrist and the palm of the hand must be treated in dorsiflexion.
4. For wounds in the flexure of the hip, the thigh should be in a line with the body, slightly abducted.
5. In wounds of the back of the thigh the knee should be kept straight.
6. The foot must be kept at right angles to the leg.

Third Stage. When wounds have already reached the contracting or fully contracted stage they are often even then amenable to mechanical treatment. As early as in 1884 a girl of fifteen was brought to me with her wrist acutely palmar-flexed, due to the contraction of scar tissue following a burn experienced ten years earlier. She would not submit to a tagliacotian operation, so I gradually, during a period lasting some weeks, brought her wrist into dorsal flexion, and kept it in that position for many months, with the result that no recurrence of contraction took place and an excellent range of movement resulted. This experience has served me well in many subsequent problems where the stretching of scar has been involved.

The stretching must be continuous and the correction is not so much due to the actual yielding of the scar as to the stretching of the healthy skin which surrounds it.

Fully matured fibrous tissue has no more tendency to contract than any other tissue, but as it takes a long time to mature the extension must be long continued. Remember also that excessive granulation favours firm contraction.

Ischæmic paralysis will be dealt with in the section relating to the hand.

OPERATIVE TREATMENT OF SCARS

Operation may be needed in any of the following conditions:

1. Painful scar.
2. Scar bound down to muscle.
3. A firm scar involving the elbow or wrist.

Scars giving rise to stiffness of joints are sometimes extremely hypersensitive. They should be excised, and if possible the cut edges should be submitted to immediate suture. If this is impossible a plastic readjustment should be done. The wound should not be allowed to heal by granulation tissue. The excision should be complete. When the scar is bound down to muscle the dissection may be quite extensive, and it is very necessary to proceed with caution. Nerve trunks may have to be exposed to avoid accident, for to be successful the completest possible removal of cicatricial tissue is called for. Cicatrices resulting from gunshot wounds can in a large proportion of cases be removed, leaving sufficient skin for suture. After operation the malposition of the joint should be quite overcome and the position maintained until the wound is healed.

Firm scars of an extensive character may involve the wrist in dorsi- or palmar-flexion and the elbow in flexion. After the removal of these it is possible that no skin is available to cover the wound. It is best then to fix the edges of the wound of wrist or elbow to a flap dissected from another part of the body. The elbow, for instance, if it cannot be straightened can be attached to the breast.

The edges of the wound following removal of a scar from the dorsum of the wrist can be attached to the abdomen by means of a cuff incision.

When the operation has been performed upon the front of the wrist a very comfortable position is to place the hand just in front of the trochanter.

During and after operation certain points must be noted:

(*a*) The excision must be complete, leaving a healthy flap for fixation. The flap should contain its fat and cellular tissue.

(*b*) No tension must be allowed on the flaps.

(*c*) The stitching should be meticulously accurate.

(*d*) Immobilization of the wound should be secured. This often is only possible by using plaster of Paris.

When the donor flap is removed it is often a wise precaution to remove it gradually so as not to cut off the blood-supply too rapidly with the resulting danger of necrosis. It can be removed in stages.

An indication of the vitality of the flap can be gleaned by tying the base of it with a piece of sterile bandage and noting the result upon the attached

edge, and again by noticing whether the distal portion bleeds if incised. A flap which looks very healthy before separation may die if ruthlessly severed.

Skin grafting and skin transplantation are useless unless the malposition of the joint is first fully corrected.

THE TREATMENT OF FIBROUS ANKYLOSIS OF A GRAVER TYPE

This type, so very common, will tax to the utmost a surgeon's ingenuity and patience.

The conditions which illustrate this condition are illustrated by :

(*a*) Stiffness due to very prolonged immobilization following compound fractures of the femur ;

(*b*) Stiffness following a sharp attack of arthritis with or without erosion of cartilage ;

(*c*) Following suppuration about the joint ;

(*d*) Fixation of quadriceps to femur ;

(*e*) Fixation of patella to bone.

During the early years of the war the treatment of fractures of the femur was not understood, and most of the cases exhibited, apart from bony deformity, an ankylosis which was often almost and sometimes quite complete. Where it was only necessary to keep the knee fixed for a few weeks it made little difference whether it was completely mobilized or not. The stiffness which resulted was only slight and could be overcome rapidly and effectively in a few days, or, at the most, in two or three weeks by massage and passive movements. In badly compound fractures, such as occurred in this war where union is slow and sepsis rife, we find knees have been kept immobilized for twelve months and more, and we are faced with a much more difficult task which requires very careful handling. In such cases any attempt at forcible bending, as understood in the slighter cases of peri-articular adhesions, should be strongly condemned as a bad procedure. It has resulted in many instances in a refracture of the femur with the lighting up of septic foci ; in fracture of the patella ; in rupture of the quadriceps or ligamentum patellæ ; and in some instances in a violent traumatic arthritis. Our orthopædic centres have had to treat many tragic instances of this.

Whenever we desire to mobilize a stiff joint, which has resulted from prolonged immobilization due to fracture, we must protect the fracture against strain. This is done by firmly fixing the fracture before applying force to the joint. For this purpose I usually apply gutter-splints of sheet-iron to the limb protecting the bone in its whole length and stopping short opposite the line of the articulation. This in addition deflects the strain from the consolidating fracture, and the full force of the effort

is applied to the joint we require to move. This precaution should be taken whether we deal with a comparatively recent or an old compound fracture. Fractured bone takes much longer to consolidate than we were taught to believe, and if any unusual strain is thrown upon a fracture which appears to be firmly united it will often yield. In gunshot fractures of the femur the callus remains soft for several months after so-called union has taken place.

There are two ways in which we can safely attempt to bring about mobilization in this class of case :

(*a*) Gradual flexion on a splint in successive short stages.
(*b*) Forcing in successive stages under anæsthesia with rest in splints during the intervals.

This method of attack is suited to the stiffness of prolonged immobilization ; traumatic arthritis and cases where suppuration has occurred about the joint.

I will therefore confine myself to a description of this procedure.

I have often pointed out that joints which will not yield at all to manipulation under an anæsthetic, will often do so when subjected to the force applied by gravity simply assisted by a bandage. Furthermore, in a joint, such as the elbow, a flexion which cannot be brought about in safety by one manipulation can often be achieved by continuous stretching of the shortened structures. I will illustrate this, taking the elbow and knee as examples, because a most important and practical principle is involved.

It is desired in an old arthritis, or in old dislocation backwards of the forearm, to bring the elbow from an obtuse to an acute angle. Under an anæsthetic the surgeon, after considerable effort, succeeds in gaining 20° of flexion. He now feels that any further attempt will result in fracture as further movement is firmly obstructed. The arm is fixed by a sling in this position, i.e. in the position of the greatest possible flexion, and in a few days the surgeon makes another effort. He will then find that he can with but little effort bring about further flexion, which would have been quite impossible with infinitely greater effort on the first occasion. In a few days another trial may have to be made to secure the full extent of the flexion needed. The ligamentous structures at the back of the elbow slowly yield under strain, and this is true of shortened ligaments in the same way as in the case of scars.

The same principle will obtain in the case of the knee, but in our attempt to flex a straight knee we have the advantage of the action of gravity. If the knee admits of, say, 15° of flexion, a long posterior splint is applied set at an angle of 15° more. The limb is bandaged to this, and when the extra 15° has been gained, the knee is kept

rested on the splint for a few days in order to relieve the strained tissues. The bandage is then removed from below the knee and the joint allowed voluntary movement within the range of the newly-gained 15°. When this has been secured the splint is bent another 15°, and the procedure is repeated. This is continued until sufficient flexion is obtained to enable the joint to be more vigorously exercised, first by active and then by passive movements. There must always be the power of full extension of the knee voluntarily. If the knee becomes firmly fixed in its new position of flexion it is a sound clinical proof of an arthritis, which must be treated with the joint fixed in the best position in view of possible ankylosis. When we deal with the stiff joints of fingers we will see that extension added to flexion will be of material help.

As we shall often have to allude to the angles of flexion it will be wise, as Broca has suggested, to standardize our methods of measurements.

For joints, such as the knee and elbow, we must estimate the degrees of extension and of flexion by regarding the 0° of one as the maximum or 180° of the other. An elbow or knee in the straight position should be stated to have 0° of flexion or 180° of extension, and they should always be estimated in correspondingly opposite directions. Thus 45° of flexion can also be expressed as 135° of extension. In the case of hinge-joints the right-angled position should be synonymous with semiflexion or semi-extension. These measurements can be accurately interpreted by a goniometer.

TRUE ANKYLOSIS

In dealing with ankylosis which requires operative correction of the angle of fixation—whether this be due to bone or not—I propose to speak of it as ' true ' ankylosis. For clinical purposes, in spite of certain objections, I think this is the most useful definition. By bony ankylosis is meant a synostosis, i.e. where bone is united to bone without the intervention of other tissue. It is usually the result of suppuration in the joint, although it is sometimes met with as the result of gunshot wound without suppuration. No ' true ' ankylosis ever occurs from uncomplicated prolonged immobilization in a normal position, where the joint has not been primarily affected. The term *true* ankylosis must be confined to conditions where the joint surfaces have been involved.

A further most useful classification introduced by Thomas is that of ' sound ' and ' unsound '. The term ' sound ' ankylosis implies the absence of active disease. In a sound ankylosis the flexion angle will not be altered by use. In an ' unsound ' ankylosis the deformity imperceptibly increases until its extreme limit is reached. The increase in the angle of deformity does not imply an increase in the range of mobility,

for an increase in the range of mobility denotes a recovered joint. An unsound ankylosis should be treated by absolute fixation. It always denotes active disease although it may be almost or wholly painless. The deformity accompanying an unsound ankylosis can usually be corrected by mechanical means. When the inflammatory element has been overcome after fixation, an unsound ankylosis becomes a sound one. An unsound ankylosis has to be treated with a view of its becoming a true ankylosis. I will now discuss the position of election for ankylosed limbs.

FIG. 158.

Shoulder-joint. The arm should be abducted to about 60° from the side. The elbow-joint should be slightly in front of the coronal plane of the body (Fig. 158), so that when the elbow is at right angles and the forearm supinated the palm of the hand is towards the face. The arm is placed in this position while the scapula retains its normal position of rest. In this position (Fig. 159) the hand can be easily made to reach the mouth by merely bending the elbow. Again, the humerus being fixed at this angle to the scapula the arm can be lifted a considerable height by scapular action ; pockets can be reached, a glass of water can be carried to the mouth without spilling its contents, and various essential

acts can be performed with ease. If ankylosis is feared *the arm should never be kept to the side,* or the result will be functionally bad (Fig. 160)—not only will it be difficult to reach many parts of the body, but difficult to reach across the table or to perform many simple movements constantly recurring in everyday life. In dealing with the question of fixation of flail shoulder, I will deal further with this matter.

Fig. 159.

The Elbow-joint. Before fixing the elbow-joint the calling of the patient should be considered and a consultation held with him in order to obtain his views. The greater number of men prefer an ankylosis about a right angle. If both elbows are ankylosed it is best to fix one slightly less and the other slightly more than a right angle. The ankylosis commonly met with at about 130° is functionally bad.

A right-angled fixation enables the patient to move his hand to his mouth, button his clothes, brush his hair, and reach across a table. At an angle considerably less than this it is more easy to get the hand to the mouth and to various parts of the head, but limitations in other directions more than counterbalance these advantages.

Forearm. If the movements of pronation and supination (Fig. 161) are both lost the radius should be fixed midway between pronation and supination. From every point of view, æsthetic and practical, this is the position of election. I will deal in a subsequent section of the mobilization of such ankylosis.

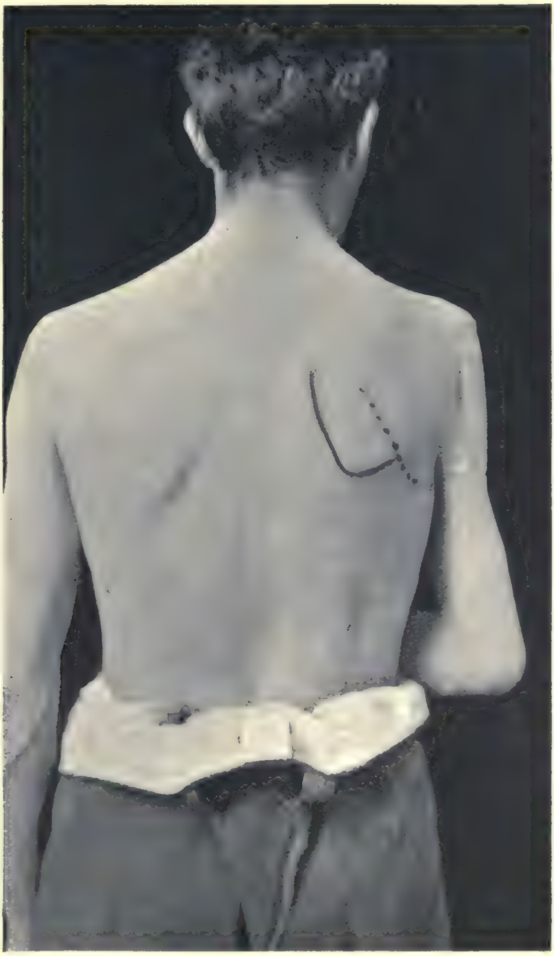


FIG. 160.

Wrist-joint. All injuries of the wrist-joint should be treated with the wrist dorsiflexed. This is an axiom which does not admit of question. It is equally true where ankylosis is expected, or where limitation in movement is likely. The common deformity which results in an arthritic wrist where no splint is applied, or where even a straight splint is applied, is that of palmar flexion, and the position is a very serious disability

while it lasts. It is so serious that when a wrist is brought to me with true ankylosis I invariably operate upon it in order to fix the wrist in dorsiflexion (Fig. 162).

The reason I advocate dorsiflexion is primarily due to the fact that in this position the grip of the fingers is strengthened, although even from the æsthetic point of view this position is indicated. A palmar flexed

FIG. 161.

wrist is always an eyesore. When dealing with stiff fingers, the use and abuse of the 'dorsiflexion' splint will be referred to.

Hip-joint. Ankylosis should be secured in a position of very slight abduction with thigh extended and with very slight outward rotation. The common deformity in ankylosis of the hip is flexion, adduction, and internal rotation, which is the characteristic position in which we find the untreated tuberculous hip-joint. It is accompanied by an ugly limp and a certain degree of lumbar lordosis. Adduction deformity brings the limb too near the middle line; interferes with the normal position of the sound limb on walking, and by

involving the sound limb in abduction it interferes with a free swinging gait.

If the hip-joint be ankylosed in the fully extended position, lordosis and the consequent trouble from backache are avoided, and there is freer pelvic movement in walking if the thigh is slightly abducted. The limb should also be very slightly rotated outwards to avoid the unpleasant lift of the pelvis as the patient rises on his toes when walking. The walk is easier if the toes are not pointed straight forwards.

Knee. This joint should be fixed in an extended position. In recommending this position I know I am at variance with certain distinguished American colleagues, who prefer an angle of 135° of extension. Good

FIG. 162.

reasons may be given in favour of slight flexion from the point of view of elegance in repose and that of ease in mounting stairs. Due weight should be given to these points, but in war injuries the straight position obviates many risks. Ankylosis, as we know, is not always bony, and if not the tendency is for the flexion angle to increase by exercise—unsound ankylosis. The incidents of body-weight on a slightly bent knee, unless the ankylosis is sound and bony, will increase the flexion. The position, therefore, is mechanically a weak one for carrying body-weight. Even when bone is forming its complete consolidation is sometimes a slow process, and if the surgeon places such a consolidating knee in a flexed position, the degree of ultimate flexion is often greater than he would wish. The advantage of increased strength and stability ensured by an extended joint will outweigh all other considerations. In taking a wedge from a knee bonily ankylosed in a flexed position where fixation in any

position becomes easy and bony fixation certain, it is an open question whether slight flexion may not be indicated.

Ankle. At the beginning of the war I advised surgeons to ankylose the ankle-joint at a right angle. After examining a large number of cases I have arrived at the conclusion that where ankylosis has occurred at the tarsus or at the joints of the toes, the foot should be ankylosed a few

FIG. 163.

degrees more acutely dorsiflexed than a right angle (Fig. 163). This enables the patient to walk with the minimum of strain upon the front part of the foot. The ankle should be so fixed that neither valgus nor varus should be evident. The slightly varoid deformity is preferable to the slightly valgoid one.

TRUE ANKYLOSIS

(*a*) In good position.
(*b*) In bad position.

(*a*) **Ankylosis in Good Position.** We have already learnt the position we consider good from the point of view of function. Obviously no opera-

tion is even needed in this condition except with the view of mobilizing a joint, and here each case must be judged on its merits. There are many factors to consider, such as the joint affected, the type of destruction to which it has been subjected, the relative functional values of stability as opposed to mobility, the dangers of recrudescence of sepsis, the condition of other joints, the state of the muscles, the integrity or otherwise of the nerves, and especially the opportunities which will be offered for efficient after-treatment. We will deal more fully with these points when discussing individual joints.

(*b*) **Ankylosis in Bad Position.** When a joint is ankylosed in a faulty position an operation will be needed to secure the best function. In some of these cases an ankylosis in an improved position will be aimed at; in others mobility may be desired. Improvement of function should be our sole aim.

The operations which we have to consider are:

(*a*) Subcutaneous osteotomy;
(*b*) Open osteotomy;
(*c*) Removal of bone wedge;
(*d*) Excision of joint, partial and complete;
(*e*) The removal of bony outgrowth;
(*f*) Pseudo-arthrosis of joint.

The operation we employ varies in different joints, and may vary in the same joint.

THE SHOULDER-JOINT

We are accustomed to estimate the degree of functional disability in the case of a stiff shoulder by the degree of abduction and rotation. Abduction of the arm may be interfered with by fixation of the scapulo-humeral joint, and also by fixation of the scapula upon the chest. This latter condition was very rarely met with before the war, but I have seen many instances since. It will be remembered that if the scapula be fixed abduction of the humerus cannot be carried in the frontal plane to above the horizontal. Further abduction is prevented by the tension of the lower part of the capsule, and can only be brought about by rotation of the scapula. The degree of scapulo-humeral abduction is estimated by observing the movement of the lower angle of the scapula when the arm is abducted. If ankylosis is present the scapula moves at once, and any lesser limitation can be accurately noted. If the scapula and humerus are fixed, no abduction of the arm is possible. Prolonged immobilization will sometimes limit abduction by the occurrence of shortening of the muscles attached to humerus and scapula.

Unreduced Dislocation. Simple unreduced dislocation is often accom-

panied by stiffness due to the position of the head of the humerus, and also by adhesions the result of effusion. If such dislocations are only a few weeks old reduction can usually be effected. This I find is most easily done by a Thomas ring attached to a chair, upon which the patient lies (Fig. 164). The arm is pulled in a plane horizontal to the body, care being taken not to put any pressure on the axilla. The pull should be steadily continued for several minutes if necessary, and when reduction is nearly complete the arm, still under traction, should be slowly brought down to the side. A dislocation of several weeks' standing can in this

Fig. 164.

way usually be reduced in a few minutes without risk of damaging vessels and nerves. To prevent a recurrence of the displacement the arm should be pulled in adduction across the chest and kept at rest for fully fourteen days. When movements are prescribed, the manipulations should be very carefully performed, the head of the bone being supported by a padded fist in the axilla.

In a dislocation of many months' standing, an open operation may have to be performed with the view of reducing the dislocation, or, failing that, removing the head of the bone, and lifting the shaft towards the glenoid.

Operation should only be resorted to if the function of the shoulder-joint can be improved, or for the purpose of relieving nerves or vessels from

pressure. The approach will depend entirely upon the position of the head, but where possible a straight incision from coracoid down should be adopted. The replacing of the head into the glenoid is facilitated by introducing a grooved spatula which is made to act as a shoe-lift.

I have not yet met with any result after operative reduction of displacement which is perfect, although some cases exhibit a moderate and staple range of movement. I have seen two instances where ankylosis resulted without suppuration. In one case, the position of the joint was that of election, and was an excellent result. The other required an osteotomy through the neck of the humerus to abduct the arm.

Position of Election. I have stated before that the position of election of the humerus should be 60° from the side, or a little more in case of the young. The elbow should be a little in front of the mid axillary line. Care should be taken not to rotate the arm too much outwards. All cases of injury to the shoulder likely to end in ankylosis should have the arm fixed in this position.

Peri-articular Adhesions of the Milder Type. This condition follows immobilization following injuries to the joint such as dislocation, fracture of the neck of the humerus, osteomyelitis of the shaft of the humerus, and injuries to elbow or forearm when the limb has been kept immobile. This stiffness can mostly be avoided by recognizing the importance of systematically exercising the joint and by keeping the arm in the abducted plane when fractures of the upper shaft are being treated. When the stiffness is due to direct trauma of the structures about the joint the symptoms are usually as follows: pain on pressure over the front of the joint about the coracoid and biceps tendon; inability to place the hand behind the back or behind the head; and limitation of abduction. The patient can, however, lift weights and adduct his arm. If the adhesions are too firm for manipulation and stretching by the masseur, it will be necessary to give an anæsthetic and to break them down in the manner already described. The movements secured should be maintained by appropriate exercises, mainly of a voluntary kind, assisted by the masseur. When the adhesions have been broken down, the arm should be kept in full abduction until the patient recovers consciousness. This is useful from the psychological standpoint.

If the adhesions have followed a fracture of the humerus, the arm must be protected by splints while the shoulder is manipulated in order to prevent a refracture (Fig. 165). Great care should be taken when the arm is rotated, especially in the outward direction, because it is then that a fracture is likely to take place. Such movements should always be supervised by the surgeon, as refracture has often occurred in consequence of the manipulations of the masseur.

Adhesions of a firmer type are usually due to the effect of injury

to ligaments or muscles, or to the extension of suppurative processes to the structures outside the joint.

In such cases the breaking down of adhesions is to be condemned. The approach must be of the nature of a careful adventure. The arm should be gradually brought up to the position of election, and fixed there in an abduction splint. It may be necessary to administer an anæsthetic before this can be done. When pain and tenderness have passed away the patient may be allowed to lift his arm upwards from the abduction splint until this can be performed easily and without pain. Then the

Fig. 165.

abduction splint can be lowered and a larger range of exercise practised, and this process can be continued until the splint is removed. If the range of movement diminishes with use then, according to our axiom, freedom has been allowed at too early a date.

If stiffness is associated with an irregular joint surface, ankylosis will probably result, but if the irregularity is the result of a non-suppurative gunshot injury, mobility may be eventually regained. Such a joint should not be manipulated, but all effort at movement should be of a voluntary kind. If the range of movement should diminish by use, rest should be prescribed ; but even if the range of movement increases, manipulation and passive movements should not be allowed.

Fixation of Shoulder by Scar. Firm scars fixing the humerus in adduction are very difficult to deal with. Unless they are situated in the folds of the axilla, excision is extremely hazardous because of the structures with which they are associated. These large wounds should, in accordance with the preventive principles I have already laid down, be treated in the position opposed to their contraction. The arm should be well abducted until the wound has granulated and is covered by skin, which may have to be brought over by an adequate flap. Whenever skin can be borrowed to obliterate a scar in the apex of the axilla it should be used. Scars in the folds of the axilla can usually be stretched. When scars are associated with involvement of the deeper soft structures, gradual stretching as distinguished from forcible or sudden stretching is clearly indicated. This gradual stretching is best effected by splints.

When stiffness is due to osteomyelitis of the upper part of the humerus it is advisable to operate upon the arm before trying to restore mobility to the shoulder.

Here, as in all other sites, the operation should be of a thoroughly radical character. There should be a full exposure and a free clearance of all dead and infective tissue. A disregard of this obvious surgical procedure is responsible for a large number of our chronic cases.

True Ankylosis of the Shoulder-joint. If a shoulder is *ankylosed in the correct position* few surgeons would wish to alter it. In my own practice I am content with this result, and on the few occasions where I have operated by procuring an arthroplasty, there have been special circumstances which have influenced me. One of these circumstances has been a fixed scapula, and sometimes when pressure has been brought to bear upon me and I have found a limited synostosis of the joint, with no bony outgrowth and a clearly defined head. In spite of exceptions of this type I would emphasize my belief that a shoulder ankylosed in good position produces the best functional result.

True Ankylosis in a Bad Position. There are two operative procedures :

(*a*) Osteotomy.
(*b*) Resection.

Osteotomy through the neck of the humerus is that which is usually demanded. It is as successful in improving function as is osteotomy of the upper part of the femur. An incision is made through the anterior fibres of the deltoid and a section through the bone is effected by a chisel. The operation should be conducted with care, a sandbag being placed behind the shoulder. The arm should be fixed for a few weeks in the position of election. A range of scapular movement may be secured which allows of easy feeding of abduction to well beyond the right angle, while

the hand can reach the pockets and, with a little knack, the collar can be fastened behind. The arm should not be rotated too far outwards. This operation must not be performed in any case where the muscles of the shoulder girdle are not acting with vigour or where the rotation of the scapula is interfered with.

Arthroplasty, or excision of the shoulder, is sometimes a success and often a failure. It is indicated where the scapula is fixed and where a good deltoid is found. It is contra-indicated where a large mass of bone is collected in the axilla. The best routine incision is the anterior one between the deltoid and the pectoralis major curving upwards and backwards over the shoulder in order to ensure an exposure of the deltoid and acromion. A flap of subcutaneous tissue and deep fascia is turned downwards and left hanging by a pedicle. The ordinary routine excision is then practised, the operation being a great deal more difficult than when the joint is mobile. The head is separated from the glenoid with a curved arthrodesis chisel. Where it is possible the muscles are detached from the greater tuberosity, the arm being rotated inwards by an assistant. The limb is next rotated outwards, and the detachment of the subscapularis proceeded with. If the biceps tendon is intact, it should be preserved, and as much bone as is necessary can be removed with a gigli saw. There should be as little rough handling as possible. Now that the humerus is out of the wound, it can be shaped so as to resemble a head. The flap of fascia is now passed round the head of the humerus and the parts stitched. The arm should be fixed on an abduction splint in the position of right-angled abduction, under moderate traction, and massage with voluntary movement from the splint started early.

If, in addition to the ankylosed shoulder, stiffness of the arm and fingers is found, these complications should be treated first of all before any attack is made upon the shoulder-joint.

Sir Harold Stiles maintains that if the shoulder is ankylosed in a bad position ; if the deltoid acts ; and if the end of the humerus has not been too much comminuted—that is to say, if it has not been replaced by a large mass of bone ; and if there is not too much scar tissue about the muscles inserted into the upper end of the humerus, an attempt should be made to get a movable joint. This limits the operation to a comparatively small proportion.

He operates by making an incision down the axis of the limb, beginning at the lower border of the clavicle a little internal to the coracoid process. To this incision he adds a short transverse one which divides the anterior fibres of the deltoid. All scar tissue is removed, and if the ankylosis is osseous the head is separated from the glenoid with hammer and chisel. The muscles inserted into the upper end of the humerus are separated subperiosteally, these being taken to preserve the long head of the biceps.

Bone is removed from the head of the humerus so as to leave a rounded extremity which is filed smooth and Horsley's paste rubbed in. The glenoid is made smooth, and, if necessary, a slice of bone removed from it. The limb is then put up in the abducted position by means of a Thomas ring splint, and extension is applied. At the end of a fortnight the degree of abduction is changed every twenty-four hours. It will be noted that Stiles uses Horsley's wax in preference to facial flaps. In one case shown to me at the Edinburgh Orthopædic Centre submitted to this technique, the patient was able to lift his arm well above the shoulder.

It must be remembered, however, that arthroplasty of the shoulder is by no means always a success. It sometimes results in a flail or weak joint, and sometimes in a painful fibrous ankylosis. Before such an operation is decided upon, the various arguments for and against should be placed before the patient. A bony fixation in good position after a few months gives an excellent and increasing range of movement, and I have seen results where the opposite shoulder, back of neck, back of hip, trousers pockets, and mouth can be reached.

The conditions favourable for operations where mobility is aimed at are :

(*a*) Where the deltoid is acting well, but the elevators of the scapula are destroyed ;
(*b*) Where the contour of the head of the humerus is not obliterated ;
(*c*) Where mobility rather than strength is desired ;
(*d*) Where the glenoid and the acromion are absent.

The question of mobility should not be considered

(*a*) Where the deltoid or where the muscles attached to the tuberosities are destroyed ;
(*b*) Where a mass of bone is present in the axilla due to comminuted fracture ;
(*c*) Where strength is preferred to mobility ;
(*d*) Where an ankylosis in good position exists.

An operation to produce ankylosis of the shoulder is never indicated where the muscles governing scapular movements do not act.

From my observation of cases examined at the various centres, I would emphasize conclusions I have formed, namely, that, for a working man, an ankylosis in good position provides the surest functional success.

CORRECTION OF FAULTY ANKYLOSIS OF THE SHOULDER

This is frequently indicated as so many shoulders have been allowed to ankylose in adduction with a certain degree of internal rotation. Correction can usually be effected by a simple osteotomy.

Osteotomy of the humerus to correct malposition of the shoulder

should only be performed where bony ankylosis is present. It never should be done if ankylosis is fibrous. When osteotomy has been performed in the presence of fibrous ankylosis the weight of the arm has always allowed the deformity to recur.

If there is a great deal of thickening at the upper end of the humerus it may be necessary to remove a wedge of bone with its base outwards. As a rule, however, a simple osteotomy suffices, and, where possible, it is best to make an osteotomy through healthy bone if that can be effected sufficiently high up. The incision can be made anteriorily. Although the deltoid is not of much importance where ankylosis exists, it is not advisable to interfere with the circumflex nerve.

After the operation the arm should be fixed and maintained at the appropriate angle which we have already discussed.

ON ANKYLOSING AN UNSOUND PAINFUL ANKYLOSIS BY BONY FIXATION

This procedure is sometimes called for, and in the case of the shoulder it is essential that precautions are taken to ensure a sound bony fixation. Many cases, more especially where a flail condition exists, have failed to firm up. By making a free exposure of the joint—the incision will vary under different conditions—the base of the coracoid, the glenoid, and the under-surface of the acromion can be explored. The base of the coracoid should be chiselled, and the flaps of bone left attached. The acromion should be denuded on its under-surface and half sawn through. The upper part of the humerus should be freshened and flaps of bone left attached. The end of the bone should then be pushed into the prepared glenoid and lifted into its correct position. The acromion should then be bent downwards and pushed on to the humeral shaft; where a bed is prepared for it by chiselling a groove in the humerus. In this way we can provide for a sufficiently extensive callus exudation to minimize any risks of failure.

THE ELBOW-JOINT

False Ankylosis. This may be due to:

(*a*) Extra-articular adhesions;
(*b*) Shortening of capsule;
(*c*) Myositis ossificans;
(*d*) Old dislocations and fractures into joint;
(*e*) Fixation due to suppuration about joint.

(*a*) *Extra-articular Adhesions.* The joint should be gently moved through its complete range of movement and rested until it recovers from the assault. We desire to release the joint from obstructive bands, and this must be done in such a way as to minimize reaction. Once and

once only should it be flexed, extended, pronated, and supinated at each manipulation. This can be repeated each day or at longer intervals according to the degree of reaction produced. The 'to and fro' oft-repeated method must be utterly condemned. We must be careful not to add the injury caused by passive movement to an existing state of acute reparative inflammation, but wait until the reparative action quietens down. If the patient's range of voluntary movement the day after passive movement is less than before, it is a clear indication that the joint is still too actively inflamed to undergo passive movement. If after manipulation the pain is less and the range of movement increased, we may safely proceed with active and passive movement.

I agree with Elmslie that in the injuries sustained in the war the breaking down of adhesions by forcible movements is very rarely called for, and considerable injury is likely to be done by injudicious force. Where stiffness follows immediately upon a recent injury, or where the elbow is stiff after a few weeks' immobilization, the breaking down of adhesions followed by massage and active movements will usually bring about a rapid recovery. Where the immobilization has been prolonged or where it has been accompanied by even a mild arthritis, a different method of attack is indicated. In such cases the arm can be gradually extended and kept fixed for a few days in complete extension. It can then be completely flexed and retained for a day or two in this position. Again, it may be fixed for a day or two at right angles, and if no reaction has resulted massage and active movements will often bring about an increased range. I pointed out many years ago that if a limited movement exists in a joint which is placed at such an angle that fixation is imperfect the joint can usually be placed at a more favourable angle, and the degree of movement it possessed before will usually be maintained afterwards. Such joints with time and exercise will most probably become more and more mobile. Active exercises in gymnasium and workshop are most helpful here.

(*b*) *Shortening of Capsule and Adhesion of Triceps.* The shortening of the capsule may be either on the dorsal or anterior aspect accompanied by limitation of flexion or of extension. In a certain proportion of such cases extension or flexion may be brought about by gradual or more forcible movement. If flexion is limited the arm should be brought into complete flexion, and kept in that position until the tendency to recur has passed. The joint can then be released for exercise during the day, but for some time it should be fully flexed at night. Similarly if the anterior portion of the capsule is involved the arm should be placed in full extension, and later flexed during the day and extended during the night.

The capsule is sometimes so thickened and firm that no amount of force under an anæsthetic will stretch it. If an attempt is made to force

such an elbow great care should be taken to prevent fracture of the arm or forearm.

In a limited number of instances division of the capsule may be performed with advantage. This operation should be executed by lateral incisions sufficient to allow of lifting the structures from the capsule rather than subcutaneously. The subsequent treatment should be on the lines indicated when dealing with forcible movement and fixation.

(*c*) *Myositis Ossificans.* My experience of operative treatment in myositis is not too favourable. It is certain that in the early stages the elbow should be fixed at the best functional angle and kept absolutely at rest. Any attempt at passive movement increases the callus formation. Rest will often induce a reabsorption of some of the bone and undoubtedly limits the bony deposit. I have on several occasions noted instances where for months the process has ceased only to be actively induced by attempts to mobilize the joint. In one instance where a plate of bone had been quiescent for years in the brachialis anticus, the surgeon forcibly manipulated the joint with the result that ulna, radius, and humerus were involved in a massive exudation of bone which quite obliterated the articulation.

If an operation is performed it should be thorough, and is likely to succeed only in those cases where a bridge of bone is situated in the brachialis anticus or biceps. If all the bone and its covering is not removed recurrence with additional deposit will almost certainly result. With this clinical knowledge in our possession we should prepare for the worst and place the elbow in the most useful position in case of ankylosis.

(*d*) *Unreduced Dislocation of the Elbow and Fractures into Joint.* In old cases of unreduced dislocation of the elbow with very limited movement, I learnt from Thomas to perform a sham reduction—a manipulation which has often proved of immense service. The manipulation necessary to produce an imitation reduction is as follows:

Under an anæsthetic the forearm is pulled in the plane at which it lies in relation to the upper arm. The angle is usually about 125° extension. The elbow is then steadily flexed. If it is an old dislocation, it may not be possible on the first occasion to do more than flex it to a right angle. This angle is maintained for a few days and another anæsthetic is given, and perhaps still another, until full flexion is obtained. This movement of flexion in stages succeeds where an attempt at one sitting would surely fail. The arm is slung in flexion and gradually dropped until it reaches the right angle. During the process of extension it must be seen to that the patient can voluntarily flex it back to the angle from which it is dropped. This simple manœuvre will often produce a most useful elbow—much more staple and useful than could have been procured by excision.

(*e*) *Fracture into Joints.* These cases should be treated by alternate flexion and extension, combined with fixation as already described when dealing with shortened capsule. An obvious block by bone should be operated upon.

(*f*) *Fixation due to Suppuration about Joints.* The elbow which has been surrounded by septic inflammatory tissue must be approached in a very conservative manner. If painful with only a few degrees of movement we should anticipate ankylosis by placing the arm at rest in the position of election. If painful and immobile, the elbow should be kept at rest. If painless and immobile, the angle may be changed from time to time by the use of a splint or collar and cuff. Any severe reaction should warn us of the danger of continuing movement.

Stiffness due to Inflammatory Arthritic Changes. Apart from placing the elbow into a good position, it is generally advisable to leave such joints alone if they are painless and the angle of deformity does not change. If painful and rest does not effect a cure, arthrodesis or pseudarthrosis may have to be considered.

TRUE ANKYLOSIS OF THE ELBOW

Treatment of this condition will consist of:

(*a*) Fixation in good position;

(*b*) Pseudarthrosis or excision.

The relative advantages of operation for mobility or fixation are still open to discussion. It is only after frank discussion with our patient as to the possibilities and dangers that we can come to a definite conclusion as to values. The surgeon is often asked to stiffen a mobile weak elbow and to mobilize a strong fixed one. Function in the one case will depend on strength—in the other, on mobility. Given the assurance of free movement with full strength after a pseudarthrosis there can be no question of its superiority. A perfect result, however, is rarely seen. In a large proportion of cases, a varying degree of lateral mobility is found, and a certain loss of strength which prevents the lifting of heavy loads. Men who do not require the arm for hard manual work will be willing to sacrifice strength for mobility. The artisan who has an ankylosed arm in a good position will prefer it to a weak mobile one. I will content myself, therefore, with pointing out the conditions where pseudarthrosis is likely to succeed, and the type of case where it is best to recommend fixation.

Mobility *may be indicated if*

An ankylosed elbow is fixed in a bad position;
A short fibrous ankylosis exists with pain;
If the articular ends of the bones are defined;

If an ankylosis has occurred in each elbow;
If flexor and extensor muscles act;
If ankylosis of shoulder or wrist co-exist.

Fixation *is usually indicated where*
The ankylosis is in good position;
The muscles governing elbow are extensively damaged;
The ends of bone are comminuted with callus exudates;
The joint is surrounded with scar tissue;
The opposite arm has been amputated.

CORRECTION OF FAULTY ANKYLOSIS BY OPERATION

This is best done by an open operation. A posterior incision is made 3 or 4 in. in length in the vertical plane, and a subperiosteal osteotomy is performed. There is no necessity to remove a wedge.

If the joint is comminuted an osteotomy should be planned through the lower part of the humerus just above the joint. The joint is then fixed for six weeks.

In the absence of pronation and supination, the head of the radius should be removed and the periosteum should be sewn over the divided end. This operation should not be done at the same time as the osteotomy. It should be before or after, otherwise the necessary passive and active movements, so essential to success, cannot be proceeded with. Recurrence of fixation occurs sometimes after removal of the head of the radius. This is usually the result of callus exudation. To minimize this risk the head of the radius should be removed very freely, and Horsley's wax, as recommended by Stiles, should be rubbed into the cut end of the bone; or periosteum should be stitched over the bone; or fascia should be wrapped round it. As a preliminary the end of the bone should be well rubbed by a smooth steel implement.

EXCISION OR PSEUDARTHROSIS

It will be in the memory of many surgeons that in the days when the usual classical excision of the elbow was exclusively practised, very excellent results were often obtained. When examined many years afterwards these cases gave evidence of considerable power and stability. Muscular control became much more marked with time. I can recall a great number of excisions in the adult, and the successful cases have always been those where sufficiently free removal of bone has been practised. The incision I have always adopted is the posterior one. It should be about 4 in. in length with its centre opposite the prominent tip of the olecranon. The points upon which stress should be laid are the preservation of the insertion of the triceps and its expansions into the deep fascia

of the forearm over the anconeus ; the preservation of the lateral ligaments ; the clearing away of detached periosteum where ankylosis is bony to make a preliminary section of the bone at the level of the joint with an osteotome or saw. The most useful line of section in the forearm should ensure the removal of the greater and lesser sigmoid with the olecranon, and the radius should be removed just above the insertion of the biceps. The section of the humerus should be above the level of the epicondyle on the outer side and through the highest part of the epitroclea on the inner side. If less is removed ankylosis is almost certain to result. When the arm is extended there should be an interval of $1\frac{1}{2}$ to 2 inches. To prevent partial dislocation forwards it is advisable to make the section through the bone a curved one, especially in the case of the olecranon.

If these points are remembered very excellent results will follow the operation of excision. The approach to the joint is not a matter of real importance, but unless the surgeon has had a considerable experience of excision I think the posterior vertical is more simple than the lateral Kocher.

The after-treatment is important. I am accustomed to keep the arm absolutely fixed at right angles under slight traction until the stitches are removed, and then very gently flexing it to an acute angle once a day for a further fortnight. At the end of that time the wrist is slung by a halter and is lowered by degrees to an angle of 120° of extension, the patient being allowed active movements. At night it is kept flexed to 60° of extension, and released in the morning. This prevents strain of the brachialis anticus and biceps, and should be continued for some weeks.

An excellent series of cases has been demonstrated by Major Jocelyn Swan, who has obtained such consistently good results that I have asked him to describe his technique.

He says :

'The operation which I have performed in these cases is essentially a subperiosteal resection with the removal of sufficient bone to leave an interval of from $1\frac{3}{4}$–2 in. between the sawn ends of the bone when the arm is fully extended. After a course of immunization by means of streptococcal vaccine and the usual aseptic preparation, a vertical median incision is made over the posterior aspect of the joint, about 5 in. in length, deepened above through the triceps and below carried through the periosteum of the olecranon and upper part of the shaft of the ulna. The tissues on each side are separated with the periosteum by means of an Ollier's rugine, particular care being taken to maintain the triceps attachment at the upper end of the olecranon. This separation is continued at the posterior aspect of the lower end of the humerus, exposing fully each condyler process and carried around the anterior aspect of the latter ; in some cases the internal condyle of the humerus has been divided from the shaft and retained, so as to leave the attachment of the flexor group of muscles of the forearm. In the lower part of the wound

the periosteal separation is continued until the inner aspect of the olecranon and upper shaft of the ulna at the inner side and the head and neck of the radius at the outer are exposed, the ulnar nerve remaining in the tissues of the inner side and not actually seen. Having thus cleared the bony surface at the posterior and lateral aspects, a strong elevator is passed across the front of the joint, raising the anterior ligament of the joint in front of the lower end of the humerus. Section is then made of the humerus in a line above the humeral condyles and in a plane at right angles to the vertical line of the shaft, when the lower end of the bone, together with the fixed ends of the radius and ulna, can be pushed backwards and the separation of the tissues in front of the joint completed. The ulna and radius are sawn off at the level of the neck of the radius and the wedge-shaped mass of bone removed, leaving a space between the two sawn ends of the bone which, with the arm fully extended, will easily admit the breadth of two fingers. Bleeding points are arrested by ligature, and any oozing from the bone ends checked by hot saline or Horsley's wax ; the incision in the triceps and periosteum is sewn up with fine thread, and the skin wound closed without drainage. The arm is put up flexed at a right angle on a moulded gutter splint. No flap of muscle or fascia is used to cover the ends of the bone or is interposed between them.

'*After-treatment.* During the first forty-eight hours radiographs are taken through the splint to ascertain that there is no lateral or forward displacement of the ends of the bones, which, if present, must be rectified. There is a tendency for the humerus to ride forwards in front of the upper ends of the radius and ulna or to be displaced laterally, which must be corrected, or the ultimate movements of the joint will be limited. The rectangular position is maintained for about ten days, when the sutures are removed and gentle passive movements commenced ; the joint is moved daily and fixed in a different position—one day flexed, the next day in extension. The patient during this period is encouraged to make easier contractions of the biceps, the triceps, and the forearm muscles. After about three weeks, active movements are commenced, the whole limb being supported on a table at right angles to the body. The active co-operation of the patient is most important at this stage. Gradually the active movements are increased and the splint discarded—the limb being supported in a sling in varying positions.

'*Results.* The results obtained have been surprisingly good. A full range of flexion and extension is usual, so that the patient can touch the shoulder of the affected side, and can actively extend to a straight line. There remains a small degree of lateral movement, but this diminishes as the power increases after an interval of six months from the operation, whilst after a further interval the functional use of the limb is still further increased. In my own cases, even with the removal of slightly more than 2 in. of bone, I have had no flail result, but I have seen limitation of full flexion where only 1½ in. of bone was removed. Skiagraphs taken some months after the operation show the formation of new bone in the separated periosteum about the ends of the bones, but this does not inferfere with movement.'

Colonel Littlewood, who took charge of the Orthopædic Centre at

Beckett's Park, Leeds, and who is a strong advocate of excision of the elbow in contrast to arthroplasty, writes me :

'I have always held that excision of the elbow, properly performed, produces a better result than excision of any of the joints, and had some difficulty in convincing some of my junior officers that such was the case. In the end I think I convinced them.

'I use the dorsal incision—no tourniquet—remove the lower end of the humerus and upper ends of ulna and radius just below the level of the radial head—if for disease more extensive, excision may be necessary. Very careful separation of triceps attachment, and, if possible, attach this to the fascia of the upper end of the ulna. Carefully stop all bleeding, and close wound without drainage.

'Fix the limb up in the flexed position at rather less than a right angle by means of a uniform wool dressing, with a fair amount of pressure —including the arm, forearm, and hand. Care is taken to put cotton-wool between the fingers and to leave only the tips of the fingers uncovered with the dressing. I leave this on fourteen days. At the first dressing I do some passive movements of flexion and extension, and apply a dressing, putting up the limb in the same position. This time the dressing only extends for a short distance above and below the excised joint, and the arm is placed in a comfortable sling. Daily movements of flexion and extension, supination, and pronation are carried out under supervision, and voluntary movements are encouraged—some massage. At night a right-angle splint is applied to keep the limb in a flexed position and to act as a guard in case of any movements during sleep. At the end of five or six weeks this can be dispensed with and all movements encouraged. Continue the sling for a time, so that the arm can rest, and not hang down.

'During the war I saw a great many cases in which a very free excision had been performed and the limb apparently put up in the extended position—a very flail-like joint with no power of flexion. The patients have been allowed to go about in this manner, with the result that the weight of the forearm pulling on the new joint, produces a great stretching of the soft parts and increases the interval between the bones. In these cases I greatly improved the condition by the use of a splint I invented. This is continuously worn. The hinge at the elbow is made to allow complete flexion, but extension is limited by a stop to rather less than a right angle. The shoulder cap is the chief point about the splint, as it prevents the apparatus slipping down, and keeps the upper ends of the bones of the forearm near the lower end of the humerus. In time these lengthened structures about the new joint become shortened, so that ultimately the splint can be discarded. All voluntary movement should be encouraged several times a day during all stages of treatment.'

ARTHROPLASTY OF THE ELBOW

It is still open to discussion whether an arthroplasty has advantages over excision sufficiently pronounced to warrant its acceptance as the operation of election. It is more difficult and requires the highest surgical qualifications of technique and judgement for its successful performance.

In the hands of the best operators it is often only a partial success. If successful it provides a stronger joint with less lateral mobility than an excision. In military surgery, however, where much shattering of bone has occurred it offers only a limited field, and is open to greater risks of sepsis. Recurrence of ankylosis is not infrequent, and a limited painful movement similar to that of a chronic arthritis sometimes results. This, I admit, is sometimes due to faulty technique, but very excellent surgeons have experienced this disappointment, and have shown me such results.

The conditions which may be suitable for arthroplasty are the following:

(*a*) Cases where a mild arthritis has caused bony fixation with an absence of scar tissue outside the joint.
(*b*) Cases with a painful and limited range of movement.
(*c*) Where a part of the joint is free.

Excision should be preferred

(*a*) In cases where the joint has been much obliterated ;
(*b*) Where there is an abundance of scar tissue ;
(*c*) Where sinuses exist ;
(*d*) Where bony masses occupy the bend of the elbow.

Neither an excision nor an arthroplasty should be performed if the function of the muscles governing the joint are seriously interfered with.

Sir Harold Stiles has advocated the use of Horsley's wax instead of fat and fascia. This procedure is still on its trial, but if successful the operation of arthroplasty will be considerably shortened and simplified. He has kindly supplied me with details of his procedure, which I repeat.

'I have now seen and operated upon a few cases where the elbow has been allowed to become ankylosed in the extended position. They have been old cases of fracture of the lower third of the humerus with secondary suppurative arthritis of the elbow joint, the limb having been treated in the extended position. In these cases one is compelled to operate in spite of the fact that there may be a considerable amount of induration and scar tissue about the joint. I have, of course, aimed at a movable joint in these cases. I have also operated for ankylosis at an acute angle if the patient's occupation demanded a movable elbow, but, of course, here I have selected only those cases where there has been a reasonable chance of success. If there has been a lot of comminution of the bones about the joint with much scar tissue and induration, then I do not advise operation. In these cases I think it is important to restore the movements of pronation and supination, and this can generally be done by excising the head and neck of the radius. In some cases we have got excellent results, in others there has been a tendency to redevelopment of the stiffening, and in more than one case we have had to

do a second operation. We now try to prevent the stiffening by rubbing Horsley's paste into the raw surfaces and by applying extension to the forearm. One of the best results I have had was in a case where extension was applied, and I am inclined to think that this was an advantage. In cases where a second operation has had to be performed I have removed a portion of the capitellum with a good result, again rubbing Horsley's paste into the raw surface.

' And now with regard to the operation for ankylosis in the extended position. There can be no question, I think, that by far the best approach is from the outer side of the joint. I prefer the Kocher's external J-shaped incision, but if there is more scar tissue and this incision does not give me sufficient access, I make a long external incision, plus a transverse incision. I first clear the outer portion of the lower end of the humerus, including the lower part of the shaft, and lower down I expose the head and neck of the radius. When this has been done, the capitellum along with the head and neck of the radius are removed. The lower part of the triceps, along with its tendon and periosteum, are then carefully separated from the olecranon, care being taken not to attempt at this stage to free the internal condyle. The olecranon fossa of the humerus is also exposed, and the parts separated subperiosteally. Having reached this stage, by using the forearm as a lever, one can break across the osseous union between the ulna and the trochlear portion of the humerus. Having done this, there is no difficulty in freeing the whole of the lower end of the humerus subperiosteally. If at this stage the ulnar nerve is in danger of being wounded, this danger is easily avoided by chiselling across the internal condyle so as to detach it along with the ulnar nerve from the rest of the humerus. The next step consists in removing as much of the lower end of the humerus as is necessary. This may be done either with a small bow saw or with a special pair of large gouge forceps (Fig. 166). The gouge blades are so made that they cut not only at the extremities of the instrument, but for about an inch on each side as well. This is a most valuable instrument for shaping the ends of bones. This reminds me to say that in shaping the lower end of the humerus one removes the greater part of the epicondyles, as well as the articular surface, but instead of leaving a straight margin to the lower end of the bone, one chips away more in the centre, so that condylar regions may project and prevent lateral movement.

' With regard to the ulna, after the olecranon has been completely freed, the coronoid is well exposed and the extremity is sawn with the bow saw in such a way as to leave a portion of the olecranon to act as a fulcrum, and, of course, a portion of the upper surface of the coronoid is also removed. Here again the special gouge forceps are used for the final trimming.

' Having satisfied oneself that the bones fit nicely when the limb is flexed, and having satisfied oneself also that enough bone has been removed, the next step in the operation consists in removing all the periosteum that has been left in contact with the separated soft parts. For example, it is very important to remove any periosteum which has been stripped up along with the soft parts off the lower part of the anterior and posterior surfaces of the humerus. The operation is completed by stitching back the muscles—that is to say, by stitching the triceps to

the supinator longus and the radial extensors with 21-day or 31-day iodine tannic catgut. The wound is then closed without drainage.

'In one of my earlier cases where I wrapped fascia lata round the lower end of the humerus, the joint re-stiffened. How far this was due to the fascia lata I am unable to say, but I am inclined to think it was due more to the fact that I did not remove enough bone. However, I have now given up using fascia lata, and have rubbed in Horsley's paste instead.

'I must say I am not quite clear in my mind as to what is the best after-treatment. It seems to me the choice lies between putting the

Fig. 166.

limb up in the extended position and applying slight extension by means of a Thomas splint. If this is done, then there is, of course, no necessity for plaster of Paris. If, on the other hand, the limb is put up flexed, then I think it is a great advantage to put it up in plaster at the time of operation. The plaster can easily be bi-valved later on for the purpose of taking out the stitches. If this method is employed, one may begin to extend the arm about a fortnight after the operation. It seems to me that the main endeavour should be to make sure of getting flexion. I think it is easier to start with flexion and then to make for extension, than vice versa.'

The splint is excellent, as it maintains extension in the flexed position of elbow and the humerus can be prevented from slipping forward.

A type of arthroplasty which has proved very satisfactory is practised by Major Elmslie, at the Orthopædic Centre, Shepherd's Bush.[1]

Major Elmslie makes a longitudinal incision for about 8 in. down the middle of the back of the arm and forearm; the skin is reflected inwards and outwards, most of the subcutaneous fat being left attached to the deep fascia. The next step is the preparation of the flap of fascia for insertion in the new joint. This flap should be taken if possible from the back of the forearm, and should be about 4 in. in its vertical measurement and as wide as possible. It includes the whole of the deep fascia and aponeurosis covering the muscles, the muscle fibres being left bare. It is turned upwards and inwards, being left attached by a pedicle about an inch wide over the inner border of the triceps tendon, opposite the inner condyle of the humerus. In separating the flap over the interval between the olecranon and the inner condyle great care must be taken to avoid injury to the ulnar nerve.

The inner and outer border of the triceps tendon are next defined, and a blunt elevator passed beneath the muscle close to its insertion. In order to get a free exposure of the ends of the bones it is necessary to divide the triceps or to separate it from the olecranon. This may be done in two ways. The muscle may be raised carefully from the olecranon with the periosteum from the posterior aspect of the bone and the whole muscle with this periosteum turned upward ; or the triceps may be split into a superficial and a deep half—the former being divided about $1\frac{1}{2}$ in. above its insertion, and the latter being separated from its insertion into the olecranon. Working with a periosteal elevator and with a knife the lower end of the humerus and upper end of the ulna are next cleared on the inner side, keeping very close to the bone and lifting the ulnar nerve and muscles in one mass. In a similar way the muscles arising from the external condyle of the humerus are stripped back, and this condyle and the orbicular ligament of the radius cleared.

If the ankylosis is fibrous the joint can now be forced open by full flexion. If the ankylosis is bony, a curved osteotome is inserted on the inner side between the ulna and the humerus and driven transversely so as to separate the bones. The joint can then be forced open. The ends of the humerus and ulna are then shaped with an osteotome in the way shown in the diagram.

The olecranon fossa must be carefully cleared out, the lower edge of the humerus cut into a transversely cylindrical form, and the front of the bone cleaned and pared down. The ulna must be cut away freely, only about half the thickness of the olecranon being left, and only a small part of the base of the coronoid process. If there is any ossification in the brachial anticus muscle this must be removed. The surfaces of the

[1] *The After-treatment of Wounds and Injuries.* R. C. Elmslie. Churchill, London.

humerus and ulna should be smoothed down with a file, Horsley's wax may be rubbed into them to seal the openings of the cancellous spaces.

The flap of fascia is next sutured over the cut end of the humerus, being brought well up to the front of the bone. Fine catgut sutures are used.

The triceps must then be sutured. If the muscle has been separated from its insertion, a hole should be drilled through the olecranon and the muscle sutured to this. If the muscle has been separated into halves these are sutured to each other by strong catgut stitches. The skin is sutured, a drainage tube being inserted for forty-eight hours. The arm is fixed upon a straight splint in the extended position. Small active movements are encouraged from the end of the second week, provided the wound is healed. No forced movements should be used, but if at the end of six weeks the patient is unable to flex the joint to a right angle flexion should be secured by the use of a collar and cuff sling. Active use is relied upon to restore movement, only gentle massage being used and all forced movements forbidden.

When the superior radio-ulnar joint is fixed it is better to do the operation in two stages. The head of the radius is first excised, and pronation and supination thus restored. When after an interval of six to eight weeks an arthroplasty of the elbow is carried out as above described. If the whole operation is done at once, attempts to restore pronation and supination will probably result in a laxity of the new elbow-joint, the movement taking place at the wrong point, and the ulna being twisted upon the humerus.

STIFF AND ANKYLOSED RADIO-HUMERAL JOINT

The position of the forearm where this joint is fixed is usually one of pronation. The ankylosis may be due to

(*a*) General arthritis of the elbow-joint;
(*b*) Comminuted or simple fracture of head or neck of radius;
(*c*) Contractions due to scar tissue;
(*d*) Synostosis of the superior radio-ulnar joint.

If the elbow-joint is ankylosed in good position, and the power of pronation and supination is absent, removal of the head and neck of the radius often partially, sometimes wholly, restores the function. It is necessary to remove sufficient bone to enable the movement to be easily performed on the operation table. The operation is destined to failure unless this can be easily done. The cut end of the bone should be well rubbed with a smooth steel implement to lessen callus exudate, and Horsley's wax applied. The arm should be fixed in supination for about ten days, and then passive movements gently performed.

The same treatment should be adopted in the stiffness the result of fracture. Care should be taken to remove all pieces of bone and to dissect away any flakes of periosteum. The incision is made on the posterior aspect of the radius.

Where the ankylosis is due to scar tissue operation is usually not so successful, as it is frequently quite impossible to dissect away all scar

FIG. 167.

tissue. An attempt, however, should be made to do this, and if at the time of operation one secures an easy range of movement a living flap of fat can be pushed round the radial neck.

Synostosis of the Superior Radio-ulnar Joint is common after gunshot injuries. If the injury is above the tuberosity, it is necessary to remove the head and neck of the radius, and completely ablate all bony union between this bone and the ulna (Fig. 167). The dissection must be free and not subperiosteal, or ankylosis will recur. The elbow should be fixed in extreme supination for a few days, alternating with complete pronation for a few days. Active movements must be assiduously practised.

THE WRIST-JOINT

Ankylosis of this joint may be due to

(*a*) Prolonged immobilization ;
(*b*) The contracture of scar ;
(*c*) The shortening of muscles ;
(*d*) Bony block due to fracture and dislocation ;
(*e*) Synostosis due to septic arthritis.

FIG. 168.

Injudicious splinting has been the cause of a large number of stiff wrists, and with the disability to the wrist must be added an almost certain obstinate stiffness of the fingers. To make matters worse, the stiffness of the wrist usually occurs in a faulty position, which adds greatly to the work of the surgeon. The arm has either been slung by the wrist, which becomes palmar flexed, or a straight splint has been applied which over extends the fingers and palmar flexes the wrist (Fig. 168). In other instances, a long cock-up splint is applied which slips upwards, and the fingers are dorsiflexed instead of the wrist. A long ' cock-up ' or dorsiflexion splint can be worn harmlessly for months in the case of children. This is not so, however, in the case of the adult. The palmar portion of the long ' cock-up ' should not be straight and flat as is so general, and it should be provided with a thumb-piece. The position of

rest for the hand is that which it assumes when it holds a large tumbler. The wrist extended about 45°, the metacarpals and interphalangeal about 30°, the thumb abducted and slightly approaching the palm. In this position all the muscles of the hand are relaxed. It is therefore very important to remember this in order to avoid paralysing the muscles and stiffening the joint.

Our first duty in dealing with the stiffness of the wrist is to dorsiflex it. This may be done gradually on a long properly-shaped dorsiflexion splint, or under an anæsthetic when often great force is needed. A short

Fig. 169.

dorsiflexion splint (Figs. 169 and 170) should then be applied, which, while maintaining the wrist in a correct position, leaves the metacarpo- and inter-phalangeal joints free. If much force has been needed the splint will be left in position for ten days or a fortnight, the fingers being very gently moved and massaged. Then the splint should be removed daily, the wrist exercised, and the splint readjusted until the deformity shows no tendency to recur.

Stiffness of the wrist due to contraction of skin or deeper tissues is conducted on the same principle as that adopted where the contraction is due to prolonged immobilization. But the dorsiflexion must be maintained for a considerable period, more especially if skin is at fault. The scar in time, by drawing upon healthy skin under tension, becomes so loose and relaxed that it loses its power of doing harm.

Stiffness due to the contraction of tendons, the result of injury to muscle, is very frequent, and it results in a condition often indistinguishable from Volkmann's ischæmic palsy. This deformity presents

a flexion of the wrist, hyperextension of the metacarpo-phalangeal and flexion of the phalangeal joints. Any attempt at dorsiflecting the wrist

FIG. 170.

FIG. 171.

results *in* further contraction of the fingers. I have many times pointed out the way to treat this condition.

(*a*) An assistant passively flexes the wrist (Fig. 171) to allow the

fingers to extend, and each finger is separately strapped to a little gutter splint (Fig. 172) so that they cannot curl up.

(*b*) A day or two later, or in milder cases at the same sitting, the metacarpo-phalangeal range is stretched, and the palm and splinted fingers are bandaged to a flat metal splint, the wrist meanwhile being fully palmar flexed.

FIG. 172.

(*c*) The wrist is now from day to day extended a little and fixed. This is continued until the wrist is dorsiflexed. The hyperextension of wrist and fingers is maintained for some time in obedience to the principles laid down concerning the extension of scars, massage being systematically practised. By this simple procedure the surgeon does much more than any operation would effect. He stretches all the scar tissues in the direct order of their tension. The muscles most infiltrated with fibrous tissue are really the seat of a diffuse scar, and the effect of continuously stretching them releases the pressure upon the vessels. One of the earliest effects of this treatment is marked improvement in the blood supply of the hand.

BONY BLOCK DUE TO FRACTURE AND DISLOCATION

The cases of fracture and fracture-dislocation occurring in military surgery bear but little resemblance to those of civil life. They are usually accompanied by laceration and comminution which add to their complexity. A scaphoid which wants removing, or a dislocated semilunar, or the rare but simple dislocation of the wrist, seldom appear before the military surgeon.

Every case of malposition should be corrected as a routine. The wrist should never be allowed to remain palmar flexed, and no excision of bone should be attempted unless we have a reasonable assurance of improved function. If masses of bone or angular splinters interfere with the function of joint or tendon they should be removed. If in an old compound dislocation attempts at dorsiflexion increase the dangers of pressure upon soft structures, bone should be removed, and an ankylosis in good position be assured. Very rarely indeed is a pseudarthrosis or excision called for. Before performing any operation which involves keeping the wrist at rest, the fingers should be made as mobile as possible.

Bony Ankylosis. If the wrist-joint is in good position, it would be allowed to remain so without operation. If the ankylosis is faulty, a wedge exsection should be performed, and the joint placed in dorsiflexion.

Ankylosis of the wrist may occur with or without loss of pronation and supination. It may be confined to the radiocarpal joint, or be combined with the lower radio-ulnar. If synostosis has occurred at the radio-ulnar joint, movements may be regained by removal of a portion of the lower third of the ulna as recommended by Baldwin of San Francisco. This operation and treatment of ankylosis of the fingers will be described in another section.

THE HIP-JOINT

We will not deal here with fixation of the hip-joint due to adhesions of a slight character, which can be dealt with in the massage department or gymnasium, but will direct our attention to the graver types, which, for convenience of description, may be divided into groups.

(*a*) Fibrous fixation due to prolonged immobilization—usually found in connexion with fracture of femur which has become septic.

(*b*) Gunshot injury to the femoral neck or trochanter with considerable scarring.

(*c*) Painful hips with limited movement, such as hypertrophic osteo-arthritis.

(*d*) Bony ankylosis.

The deformities in connexion with the hip-joint are familiar to us all from association with tubercular disease. With few exceptions similar deformities are present in war injuries. They are flexion, adduction, and usually some internal rotation. Tilting of the pelvis gives rise to considerable apparent shortening. In the earliest stages, before they appear at our orthopædic centres, many exhibit abduction and external rotation, but this is usually a transient stage. With the advent of flexion and adduction, lordosis is associated.

All flexions of the hip-joint, the result of sepsis, should be dealt with in as gentle a manner as possible. The lighting up of sepsis is a grave and often fatal calamity. Forcible movements and operative procedures should be delayed until risks are reduced to a minimum.

(*a*) Deformities due to fibrous fixation, the result of immobilization, can be treated without fear of any reaction in the joint. However, as we generally have a complication in the existence of an old fracture of the shaft, the greatest care should be taken not to do damage to this. If stiffness is not extreme, the old fracture should be protected by splints, and the sound thigh bent on to the abdomen to obliterate the lordosis, while the flexed thigh is gradually straightened. If it is found that this cannot be done without great force, the manipulation should cease, for it is very easy to fracture the neck of the femur.

The thigh, still being protected by splints, should be placed upon an abduction frame which will obliterate the flexion, shortening, and adduction. The correction will be simplified if the adductors are contracted by subcutaneously dividing them. When the deformities are corrected, it will be found that the pelvic spines are on the same plane, and that the thigh of the good leg can be placed on the abdomen without causing flexion of the unsound limb. A Thomas knee splint will replace the abduction splint, and movements of the hip may be resumed.

If after correcting the deformity the hip remains stiff and painful, it should be fixed in the best possible position until reactive change has passed.

If the stiffness does not wear away, but reacts on any attempt at movement, it should be dealt with as a case of arthritis, and, as soon as the fracture admits of it, the hips should be fixed for walking. At a later date movements may spontaneously appear, and then the surgeon's aid will be beneficial.

(*b*) Where the deformity follows a gunshot injury through the neck of the femur, treatment is attended with grave responsibility. If the fracture was septic, the bone will remain very soft for months, and it is much better to allow the deformity to remain for many months before placing it on an abduction splint for gradual straightening, or for osteotomy of the upper part of the shaft.

Where fracture of the trochanter alone exists, this precaution is not needed, and the limb can at once be placed on an abduction frame.

(*c*) Painful hips with limitation of movement have frequently been noticed amongst the men, but more particularly amongst the more elderly. These have been the result of exposure and often of hard marching, and have resulted in what we may term a traumatic osteoarthritis. They are not the result of injury from missiles.

In the young this condition becomes stationary. In the old it is nearly always progressive. The X-rays show osteophytic changes as in osteoarthritis.

In both classes the condition is often associated with adhesions which still further limit movements and give rise to pain.

Considerable improvement follows a careful breaking down of adhesions in the case of the young, followed by carefully conducted exercises by a trained gymnast.

In the elderly type it is advisable to rest the joint, and to keep it under restraint during walking. On several occasions I have had to operate upon these joints when they have been exquisitely tender—neither allowing the patient to sit nor to lie in comfort. When this has been complicated by stiffness of the opposite hip the condition is deplorable, and requires drastic surgical attack. Excision of the head of the bone is obviously a very serious operation in men over fifty. The great shock is associated with disarticulation of the head. I have, therefore, had recourse to an operation which I have found helpful on many occasions before the war. It allows of mobility, it does not involve removal of the head, it is rapidly performed, and there is scarcely any shock. It consists of pseudarthrosis of hip leaving the joint *in situ*, and will be described later.

(*d*) Bony ankylosis of the hip is not very common. Its treatment can be discussed in association with conditions which can clinically be scarcely distinguished from it. A hip which is fixed at a good angle, whether by bony or short fibrous but sound ankylosis, should be left alone unless some exceptional reason be offered. Such a hip will bear weight without complaint, and will give very little inconvenience. I know many instances where men can walk ten miles with ease in spite of the condition. In the lower extremity more than in the upper, stability counts, and operations should be discouraged.

If the ankylosis is in a bad position, this should be corrected by one of the following operations:

(*a*) Transtrochanteric osteotomy.
(*b*) Subtrochanteric osteotomy.
(*c*) Removal of wedge.

(*a*) Transtrochanteric osteotomy gives the most accurate mechanical result. It should be practised in all cases of bony fixation where the femoral neck is not absorbed, and where there is no marked pathological displacement. It may be done subcutaneously with a saw, or by an open osteotomy. I am accustomed to an Adams saw with a nob placed at its end to protect it from perforating structures or from escaping from the bone. The skin is drawn downwards as the patient lies, and a very small incision is made directly on to the trochanter. The blade of the knife passes along the front of the bone in a line starting $\frac{3}{4}$ in. below the lip of the great trochanter. While the knife is *in situ* the blade of the saw is passed below it and the knife is withdrawn. It is necessary to saw about four-fifths through the bone, when it easily yields. The adductors are then divided, if contracted, and the limb placed in abduction under extension.

(*b*) Subtrochanteric osteotomy is indicated where we wish to be far from the old seat of mischief, or where the fibrous ankylosis is in process of becoming sound. It is contra-indicated where the flexion is extreme, as the upper end will form a sharp prominence in front.

(*c*) A wedge operation is indicated where the neck and head of the femur are absorbed, and the trochanter raised, in pathological dislocations, and in conditions where a mass of bone has to be penetrated. Here also the adductors must be severed.

Before fixing the patient in an abduction frame, I often apply a pulley to the limb and bring the pelvis down on its adducted side. The degree of abduction at which to fix the limbs depends upon the shortening. The more the shortening, the more the abduction. It is now noted that the length of the limbs may be equalized in one of two or in both ways—either by lessening the practical length of the sound limb or increasing that of the short one. By osteotomy and extension a slight lengthening occurs, and by the osseous union of the femur in abduction with the pelvis, the elevation of the pelvis on the opposite side is effected. With an abducted thigh in one piece with the trunk, it is clear that the limb can only be adducted at the cost of elevating the pelvis on the sound side, and in this way several inches of shortening may be remedied. Theoretically, one should be content in bringing the anterior spines of the pelvis level, but no harm comes if the adducted side is slightly abducted to remedy the effect of the real shortening.

ON THE MOBILIZATION OF ANKYLOSED HIPS

Apart from the exceptional case where a patient insists on having movement, which he regards as more important than stability, I would confine mobilizing operations to

(*a*) Cases of double ankylosis ;
(*b*) Cases of unsound ankylosis with adduction.

Even in a case of unsound ankylosis, I should explain to the patient that a sound ankylosis could be assured him by operation, which would include a correction of his deformity and relieve him of all pain.

In double ankylosis operation is obviously imperative, and if the ankylosis is bony with the usual deformities, one limb should be submitted to osteotomy, and the other to pseudarthrosis. The shorter limb should remain ankylosed, as pseudarthrasis or excision is followed by some shortening.

The operations from which a choice can be made are

1. Excision of the head ;
2. Pseudarthrosis to reconstruct the joint ;
3. Pseudarthrosis without removing the femoral head.

The choice between an arthroplasty and an excision is often difficult. An excision should be reserved for cases where

(*a*) Disease is present ;
(*b*) There has been much comminution ;
(*c*) The contour of the bones forming the joint is lost ;
(*d*) Pathological displacement has occurred.

The Operation of Excision. The posterior approach is to be preferred to the anterior, and either the longitudinal or the Kocher incision can be used.

The Kocher Angular Incision. The patient is placed on his sound side with his hip slightly flexed. An assistant is required to change the position of the hip as required. An incision is made from the posterior margin of the base of the trochanter to the posterior margin of the summit of the trochanter, and from this point upwards and backwards towards the posterior superior iliac spine, parallel to the fibres of the gluteus maximus. The tendon of the gluteus maximus is then split in the direction of its fibres, and the deep wound is enlarged by splitting the muscle itself. When the wound is retracted, the gluteus medius is seen at its insertion into the trochanter.

The hip is now rotated inwards to bring into view the post angle of the summit of the trochanter. Having found the groove between the

gluteus medius and minimus and the pyriformis, the insertions of the gluteus medius and minimus with the periosteum from the trochanter can be separated until the intertrochanteric line is reached anteriorly. The insertion of the ilio-femoral ligament is then separated. The thigh at this stage is flexed and rotated outwards. The articular capsule is then divided along the lower edge of the pyriformis tendon, and if the thigh is flexed and rotated inwards the insertion of the pyriformis can be divided and the insertion of the obturators and gemelli can be chiselled off. This can be done with comparative ease if the joint can be moved, but if bony ankylosis exists the difficulties are far greater. In this case the whole of the posterior surface of the neck of the femur must be exposed, and a broad chisel must be introduced between the femur and acetabulum and the head levered from the pelvis. The operation is tedious and sometimes difficult. I find it simpler in such cases to approach the front by removing the trochanter in a muscle flap, and working with a broad grooved arthrodesis chisel. In bony ankylosis more bone must be removed than where the ankylosis is fibrous.

ARTHROPLASTY

Murphy's operation, as described by Binnie, but with a goblet incision, the stem of the goblet passing vertically over the trochanter, is sound and practical.

The flap is reflected containing skin, superficial fascia, and fascia lata.

With a needle and guiding suture pass a Gigli wire saw round the base of the trochanter major and divide it transversely. This may be done with an osteotome—turn the severed trochanter with its attached muscles upwards. Excise the articular capsule and separate it from the ilium all the way round. Chisel the bony material (head of femur and new bone) filling the acetabulum from the latter, beginning at the line of junction, and so cutting that as much as possible of the femoral head is retained. After cutting most of the line of union the remainder may be fractured by moving the thigh. With chisel, rongeur, and scoop, smooth and deepen the cotyloid—similarly round off and smooth the head of the femur.

Dissect the fascia lata from the rest of the original flap, leaving its base intact. With this fascial flap line the new cotyloid cavity. Fix the new lining in position by a few sutures. Only a part of the flap and that near its base is required for this purpose; the apical portion will be used to cover the femur. By manipulation return the head of the femur into the socket. Suture the free margin or apical portion of the fascial flap to the periosteum and capsule attached to the neck of the femur.

Peg or wire the divided trochanter into position, and close the wound.

In a personal communication Sir Harold Stiles has described an arthro-

plasty of the hip whereby he again dispenses with fascial intervening flaps and trusts to Horsley's wax.

He approached the joint by the Kocher method, except that the upper limb is shorter and placed higher up. The angle of the incision is more rounded, and the lower limb prolonged 2 or 3 in. below the root of the trochanter and placed a little in front of its posterior border. The upper fibres of the gluteus maximus are split along the upper limb of the wound—the rest of the muscle is then divided close to its insertion. The wound is then opened up exposing from above downwards the lower fibres of the gluteus medius, the pyriformis, the obturator tendon, the two gemelli, and the whole of the quadratus femoris. The gluteus medius is next divided close to its insertion, and the muscle retracted upwards and forwards so as to expose the upper border of the great trochanter. The pyriformis, obturator, and gemelli are then divided about $\frac{3}{4}$ in. from their insertions—also the fibres of the quadratus femoris. The inner portions of these muscles are dissected a little inwards, so as to expose the posterior aspect of the neck of the femur. Some of the posterior fibres of the gluteus are then divided and the muscle still further retracted forward so as to expose the lower fibres of the gluteus minimus, which are divided and separated from the ilium. The whole of the posterior aspect of the neck of the femur and the upper and posterior segments of the acetabular margin are then exposed, and with a periosteal elevator the ilium is cleared for about 1 in. above the margin of the acetabulum. The upper and posterior margins of the acetabulum are next chiselled away to about the depth of $\frac{1}{2}$ in. A broad-gauge chisel is hammered in between the acetabulum and the femur, and some of the head of the femur chiselled away along the acetabulum margin. These procedures are continued until by using the limb as a lever, the remainder of the bony surface can be wrenched apart. The limb is first adducted, and finally externally rotated. By this means the head of the bone is completely freed, and can then be pared down with an osteotome until about two-thirds of the head is removed and the surface rounded off with a coarse file. The acetabulum is scraped out, and all loose portions of bone removed. Horsley's wax is now freely rubbed into the raw surfaces of femur and acetabulum.

The rough and posterior parts of the acetabulum are removed before replacing the head of the bone. After replacing the head, the pyriformis, obturator, gemelli, and upper part of quadratus femoris are sutured with isotannic gut. The post fibres of gluteus minimus are not sutured. The divided insertion of the gluteus medius is united by four sutures. Lastly, the gluteus maximus is sutured—care being taken to put a sufficient number of stitches in the tendon of insertion. No drainage is used. A large dressing is applied and carefully and firmly fixed with a spica

FIG. 174.

FIG. 173.

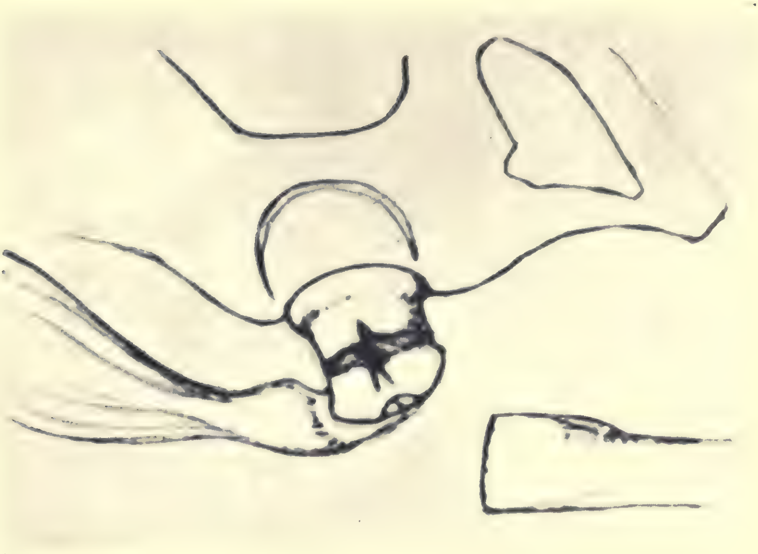


Fig. 176.

Fig. 175.

Fig. 178.

Fig. 177.

bandage. A Thomas splint with a large ring is then applied from the middle of the thigh to the ankle, the foot being retained at right angles by means of the usual sliding foot-piece.

When the patient is returned to bed, the leg is slightly abducted and the bed elevated to get counter-extension from the body weight, the splint being fixed to the foot of the bed.

I have no doubt that success is more likely to result by a very considerable reduction in the femoral head, and that it is rarely wise to scoop out the acetabulum. This procedure only adds to the risk of ankylosis.

PSEUDO-ARTHROSIS OF THE HIP WITHOUT DISARTICULATION OF THE HEAD

This operation is reserved for elderly and fragile folk who have extremely sensitive hips, and who cannot stand the shock of disarticulation. It is also suitable for cases where a mass of bone has formed around the joint. It results in a painless mobile hip, but a calliper has to be worn for some months. It is an operation devised to avoid friction, which is the cause of the acute pain in these cases.

The operation consists in removing a slice of the great trochanter, chiselling through the neck and screwing the separated portion of the trochanter to the proximal end of the neck in order to avoid union of the fragments (Figs. 177 and 178).

The operation, which is not admissible in the case of children, is performed as follows :

A longitudinal incision is made about 6 in. in length with the upper border of the trochanter in its centre.

An incision is made across the base of the trochanter, just below the insertion of the gluteal muscles.

A slice of the trochanter from this point to its junction with the neck above is sawn or separated by a very wide osteotome and retracted upwards. The capsule is now opened and the head separated from the neck with an osteotome (Fig. 173).

Extension is next put on the femur, and the trochanter with its muscles attached is screwed on to the head of the femur, which remains in the acetabulum (Figs. 175 and 178).

Deep and superficial sutures complete the operation.

In the case of a tender joint, to avoid impinging, it may be necessary to remove a portion of the neck (Figs. 174 and 176). In the case of an ankylosed sound joint the neck should be divided close to the acetabulum.

After all of these operations the limb should be kept at rest for about nine days, and then very gentle passive movements should be practised. A calliper splint should be worn in order to permit of walking without allowing any strain on the joint.

FLAIL JOINTS AND THEIR TREATMENT

BY

SIR ROBERT JONES

FLAIL JOINTS AND THEIR TREATMENT

One of the common products of the results of war injuries is the flail joint. In other words, a pseudoarthrosis, which is of very imperfect function, because the bones forming it do not come in contact, and, in consequence, the lever is imperfect because it has no fulcrum. The greater number of these disabilities are the direct results of excisions deliberately performed at Casualty Clearing Stations or Base Hospitals. They were performed in order to save the limb from amputation, or the patient from death by minimizing local sepsis and preventing general sepsis. Joints are difficult to drain, and the excision simplified the immediate problem. The only competent judges of the necessity of these measures were the surgeons at the front, upon whom rested many grave responsibilities. It is our duty to recognize this, and to try to lay down suggestions for the immediate and later treatment of these loose joints in order to minimize the loss of function.

It is well, however, to realize that upon the type of resection, as judged from cases which have arrived at our centres, largely depends good or bad function. Cases of so-called limited resection have resulted in better function than where the excision has been extensive. Furthermore, cases where the sepsis has been overcome and the bones allowed to remain in position have resulted usually in very good and firm ankylosis, with excellent function if the position of election has been maintained. There is no reason why any joint should be allowed to heal at functional disadvantage. This, however, is even yet not sufficiently appreciated. One draws attention to it, not as a matter of adverse criticism, but in case one may be tempted sometimes to excise too much bone, or to forget that many most excellent results are chronicled where excision has not been resorted to.

The flail joint may follow :

(*a*) As a direct result of excision.
(*b*) The removal of large comminuted masses of bone.
(*c*) The direct loss of bone from missile.
(*d*) The extrusion of necrosed bone during sepsis.

Methods of prevention.

(*a*) The extent of excision should be strictly limited, subject only to conditions of safety.

(*b*) Extension applied should be very moderate.

(*c*) Ankylosis should be aimed at rather than mobility.

(*a*) **The limitation of extent of excision** is very important. Muscular attachments which have important influence in maintaining good function should be spared where possible. The tuberosities of the humerus, the nerve-supply of the deltoid, the condylar attachments of the muscles governing the elbow, the triceps expansion, the biceps insertion, the coronoid, and, if possible, the whole or a portion of the olecranon should be preserved.

Again, one should endeavour to retain as much width of the lower end of the humerus as is possible, in order to allow the surgeon to restore leverage later.

If it is impossible to leave the important muscular attachments *in situ*, it may be possible to chisel off the portion of bones to which the muscles are inserted—such as the olecranon, tubercle of radius, coronoid process, and the tuberosities of the humerus. They may all be useful later for reconstructive purposes.

(*b*) We should strictly limit extension, both in extent and time. I have seen several cases where, after excision of the elbow, a Thomas arm splint has been applied for three months and more with separation of the joint surfaces for many inches. The extension should be strictly limited to the urgent needs of drainage. Strong extension of a limb where the joint has been excised obstructs free drainage. The extension, if necessary at all, should be of the lightest kind, and maintained for the shortest period possible. An abducted shoulder and a flexed elbow admit of excellent drainage. In the case of the shoulder and of the elbow, the dependent position of the arm and forearm permits of purulent tracking down the muscular planes.

(*c*) The rule should be to aim for ankylosis in the functional position. We need not again enter into the arguments for and against mobility. The fact that we aim for ankylosis does not mean we will attain it. We very rarely can, but the effort leaves us the best possible result for future reconstruction. The rule, therefore, should be that so soon as the surgeon at the front can do so, he should place the bones as near together as he can, and in the best position for future function, whether a pseudarthrosis or an ankylosis occurs.

TREATMENT OF THE FLAIL JOINT

The flail joint, as we meet it, is practically useless from the point of view of function, and it demands mechanical or operative treatment or a combination of both.

Treatment may consist of

(*a*) Removal of necrotic bone and scar tissue;

(*b*) Postural treatment;

(*c*) Operative attempts at improved pseudarthrosis ;
(*d*) Production of ankylosis ;
(*e*) Retention in mechanical apparatus.

(*a*) A fair proportion of flail joints—especially the shoulder—are infected and discharging. Where it is possible they should be treated as in the case of osteomyelitis elsewhere, by excision of sinuses, scars, and infected bone. Whether operated upon or not, the bone surfaces should be approximated and retained in the functional position. A proportion of cases take in their slack and ankylose, or result in a much firmer pseudarthrosis. The shoulder and elbow are the joints most responsive to this treatment.

(*b*) Where all wounds are healed, the shoulder and elbow should be placed in the functional position either by means of an abduction-splint or an angular elbow splint, or in plaster. The latter method lends itself very well to these two joints, and gives the much-needed stability. The bones should be insinuated into juxtaposition to each other without crumpling soft tissues between them. The fixation should be continued without an interval for at least three months.

If the muscles governing the joint retain power, the after-treatment must be carefully conducted. In the shoulder the upper portion of the plaster support should be removed, so that the arm rests on the gutter-shaped under part of the casing. Liberty should be allowed the patient to exercise his deltoid, and when he can lift it slightly from the case, the arm can be brought a little nearer to the side and fixed in an abduction splint, and a larger range of movement may then be allowed the scapula and humerus. The arm is still further lowered, until it can be safely dropped to the side. If the fixation is bony or short fibrous, the shoulder-blade becomes the joint. If there is free mobility, the deltoid may be trained to lift the arm. This it sometimes does by raising the lower fragment and drawing it against the axilla with quite a useful result. The elbow, when it is removed from the sling, should be more acutely flexed in order to strengthen the biceps and brachialis anticus, and the forearm slung by the wrist. As these muscles gain in power, the forearm can be gradually lowered until it reaches a right angle. For a considerable time it should be kept from extending further in order to retain the power gained by the flexor muscles.

Such shoulders and elbows, however, are always weak, and in the elbow a considerable lateral instability results. A hinged splint with a shoulder-cap will be of advantage in the case of the unstable elbow.

(*c*) Attempts may be made at improving the stability of weak pseudarthrosis by operation. This should only be attempted where the muscles governing the joints may be reasonably expected to recover strength.

The operations consist in the removal of intervening scar tissue and bringing the bone into contact. They may be kept together by means of kangaroo tendon or other absorbable material. In the case of the humerus a bone-graft may be used to lengthen the shaft, but we will discuss the position of bone-grafting later.

(*d*) Ankylosis of the flail joint, often a difficult matter, will be discussed in relation to the joints involved.

Flail Hip. If the femur has merely been deprived of the head and neck, all that is needed is to correct any deformity which obstructs walking—such as adduction. This can be done by division of the adductors. If the limb cannot bear weight a jointed calliper should be applied. This supplies an artificial lever, and the muscles governing flexion resume more of their function. With such a splint the patient can walk long distances with ease and strength. When the trochanter and part of the shaft are also lost, this splint proves very useful. Bone-grafting, as usually understood, is of no use to replace the upper part of the femur.

Ankylosis in the case of limited excision of the hip is of no advantage, and certainly does not justify the severe operation which it would necessarily entail. If the trochanter and part of the shaft is removed, the most likely method of obtaining an ankylosis is to take a long strip of femur half its thickness, and slide it into a prepared acetabulum. The slide should rest for two or three inches in the groove of the femur. Such a graft has a much better chance of life than when introduced from another part of the body. A thin graft removed from elsewhere never develops strength in the adult, and will refracture.

Knee. Ankylosis of this joint is the only practical treatment, and, if the bones are in good condition, nothing is needed excepting to saw the ends and fix with screw or nail. If there is a wide separation, however, and the ends have been associated with sinuses, union is not easily secured. In such a case it will be necessary, after sawing the ends of the bone, to bring a bulky sliding graft from tibia or femur and wedge it in at right angles to the line of the joint. This is a method I have often employed in secondary excisions where union has not been firm.

If there is shortening to the extent of many inches, the patient may prefer an artificial limb, and he may supply arguments worthy the surgeon's consideration.

If an operation is refused, the calliper splint and a high boot will afford the best help.

Ankle. This is so rare that I cannot recall an instance as the result of a war wound. Should it be met with, the treatment will lie between an ankylosis or an amputation.

Flail Shoulder. I have already described the postural treatment of

flail joint, and have mentioned that a successful pseudarthrosis does not often occur in the case of the shoulder. In a limited number of cases where the head of the bone only has been removed, and where the muscles attached to the tuberosities and the deltoid are functioning, abduction and carefully conducted muscle re-education may result in a joint preferred by some people to an ankylosis. The very flail joint can only be approached with a chance of success if an ankylosis be aimed at. I have seen certain cases where a graft of bone has been introduced to lengthen the shaft, and in one case the upper part of the fibula, with results which I would call promising. I have also seen cases where these grafts have refractured and have never united again, and others which have been reabsorbed, leaving the patient in a worse plight than before. The result of my experience is that I would prefer adopting a more certain route, such as the production of ankylosis by end to end apposition.

Captain Platt has described a method of bone transplant which may still be considered under trial. It is an attempted reconstruction of the head of the humerus in order to obtain a fulcrum for scapular movement. He takes a large autogenous graft from the tibia, shaped like a wooden mallet. The shoulder-joint is exposed, the upper end of the humerus cleared, and the handle of the graft driven into the medullary cavity. The wide upper end is now brought into contact with the glenoid cavity, which has been completely bared, as in an ordinary arthrodesis operation. On occasions he has used a long fascia lata sling carried through the upper end of the humerus, the upper margin of the glenoid, and the acromion process. After completion of the operation the arm is placed in abduction until stability is secured.

Many operations for fixing the shoulder have failed because the surgeon has been content to bare the glenoid and freshen the humerus. This is usually insufficient. I have already alluded to the operation I usually recommend for fixation. If the deltoid has hopelessly been deprived of function, an excellent exposure can be obtained by turning back a flap of skin and exposing the upper part of the deltoid. This muscle can be cut across or reflected upwards as a flap. The joint is fully exposed, and the glenoid can be gouged as deeply as possible. The base of the coracoid and the acromion should be chiselled, and the bone flaps left attached. The upper part of the humerus should be exposed and sawn through, and a groove made into the upper part of the shaft for the reception of the acromion. The humerus is pushed into the glenoid and the acromion sawn through and received into the groove prepared for it. The glenoid, humerus, and acromion should be fixed in contact by kangaroo tendon and placed in the functional position. Major Naughton Dunn has pointed out to me that if there be much shortening of the humerus the functional position will vary from that which I have

advocated. If there is no loss of bone the position of selection is just in front of the coronal plane of the body, while if there is much loss of bone it will be necessary to fix it in a plane posterior to this. Otherwise in flexion of the elbow the hand will pass beyond the mouth. It is advisable, before fixing the shoulder, to test the position by flexing the elbow and observing the function. Dunn described the operation which he performs. It is very similar to that which has already been mentioned. He makes an anterior incision, freshens and exposes the upper end of the humerus by partial removal of the *sclerosed ends in one or two positions*. These fragments of bone are retained with their blood-supply intact to form new attachments, and help to strengthen the arthrodesis. The under surface of the acromion is removed by a gouge from without inwards to opposite the upper margin of the glenoid cavity. This partially detached piece of bone is then folded into the space between the under surface of the clavicle and the upper margin of the glenoid cavity. The acromion process is divided about one inch from its extremity, so that it may be brought into direct apposition with a prepared surface on the shaft of the humerus. The prepared shaft of the humerus is impacted into the glenoid cavity and maintained there by suture.

After all operations to obtain ankylosis, the arm should be immobilized for three months.

Before the shoulder is operated upon, care should be taken to ascertain whether the scapula is mobile ; also whether it retains its normal position in regard to the humerus. This is extremely important. The success of the operation depends on bony ankylosis and a mobile scapula. If the scapula is fixed the result of operation is a tragedy, as the patient has a fixed abducted shoulder which he cannot lower. I have seen several such results.

After operation great care should be taken to exercise and re-educate the scapular muscles. The range of scapular movement in the young soldier increases for many months.

Flail Elbow. Two methods of treatment are available here :

(*a*) The non-operative.
(*b*) The operative.

How can we predict the case where it is useless to bring about stability without operation ?

The non-operative method consists of the approximation of the bone ends, counteracting the effect of gravity, and in muscle re-education and development. It also often involves the wearing of apparatus.

The operative treatment has one of two ends :

(*a*) The formation of a bony ankylosis.
(*b*) The provision of a mobile arm with stability.

The non-operative treatment is only likely to be successful where the bone ends are broad (Fig. 179).

If the bone ends are pointed and distant (Fig. 180), non-operative treatment cannot be successful even with good muscular control. Many

FIG. 179.

FIG. 180.

surgeons have described how difficult it is to obtain union in flail elbows. Failure is probably due to a technique which trusts too much to limited surfaces of attachment.

There is so little vitality in the ends of the bones that a mere freshening with apposition and fixation will often fail to accomplish union. When nails are driven in the result is no better, and further interference with blood supply is threatened. Operation must be devised whereby a larger apposition of raw surface is secured. This can be effected at

times by splitting the ends of the bones, and in this way widening them. Naughton Dunn has described to me the scheme he adopts, with results I know to be satisfactory.

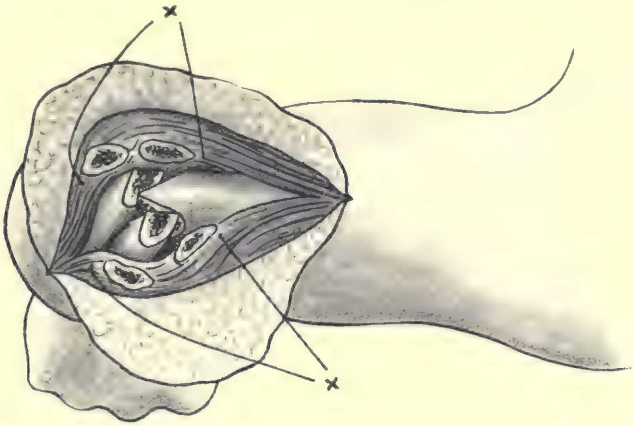


FIG. 181.

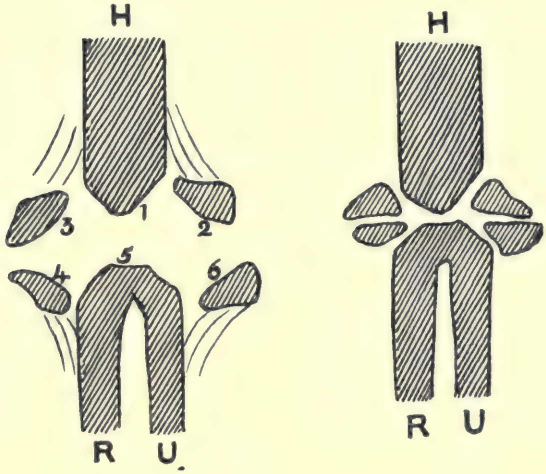


FIG. 182.

He bares the ends of humerus, ulna, and radius for about an inch from their extremities and the ends are left adherent to muscle or other tissue. The ends are chiselled off and freshened, the detached pieces being supplied with blood from the tissues to which they are attached. The bones are approximated, fixed by suture so that a broad surface for union results.

The ends of the bones as we meet them are of such a varying type that precise details of operations cannot be given, but the principle

remains that pieces of bone should be partially detached from each shaft end and wide apposition secured.

Pseudarthrosis of the Elbow. We have already discussed pseudarthrosis of the elbow when this operation is performed for mobilizing an ankylosis. It is a different proposition when we wish to stabilize a flail joint and yet permit of voluntary movement. A necessary condition to the success of this operation is a sound muscular control. If this is not present it should never be performed.

Captain McMurray has had a successful series of cases by employing a scheme which has for its object movement with improved lateral stability.

A vertical incision is made over the posterior aspect of the joint of a length varying with the amount of bone missing, and extending about $2\frac{1}{2}$ in. over the upper end of the ulna and the lower end of the humerus.

The lower end of the humerus is completely cleared from the overlying tissues for a distance of 2 in. The upper end of the radius and ulna are likewise cleared completely to the level of the orbicular ligament.

It is generally found that the olecranon has been removed at the time of wound or operation, and if this condition is present the lower end of the humerus is made into the shape of a wedge by removing bone laterally, thus (see Fig. 183, antero-posterior view):

Fig. 183.

A wedge of bone is removed from the neighbouring sides of the radius and ulna, as shown above, and this wedge is larger in extent than is necessary to contain the wedged lower end of the humerus. A flap of fascia is now prepared for placing round the lower end of the humerus to prevent any adhesions between the bones. This flap may be taken from the tissues in the neighbourhood, if these have not been destroyed, or it may be taken from the fascia lata of the thigh.

The question as to whether this flap is free or pedunculated does not seem to be of any importance, as both act equally well. Whichever flap is taken is then sutured in position round the lower end of the humerus, and this is then placed deep into the space between the upper end of the radius and ulna, so that the ends of these bones project behind the humerus.

A drill is then passed through the three bones in this position, and the relative position of the bones maintained by means of kangaroo tendon or small bone graft passed through the hole thus made.

If the triceps has lost its attachment to the upper end of the ulna it is now freed from adhesions and attached securely to the upper end of the bone.

If the olecranon is present at the time of operation, the wedge from the radius and ulna is taken at the same spot as before, and the olecranon is left projecting back from the humerus—so increasing the power of the leverage which is obtained at the elbow-joint.

The arm is flexed up in abduction and voluntary movements encouraged after three weeks. After eight weeks, the arm is allowed down by the side, and the tendency to stretching of the biceps is prevented by the wearing of a collar and cuff support round the wrist.

By varying the line of bone cuts on the radius and ulna, the forearm can be placed in any position desired.

Platt, in order to render the joint less flail, has devised an operation which consists essentially of binding the bone ends together by strips of fascia lata. After exposure and removal of scar tissue he drills the lower end of the humerus and the upper ends of the radius and ulna, and the artificial ligaments are carried through in planes at right angles to each other and tied securely—the knots being fixed by sutures—and the ends of the ligaments are then fixed to the remains of the joint capsule and the muscle insertions in this region. The limb is slung up in 40 degrees flexion, and muscle education is begun at an early stage. The training is begun in the position of abduction of the shoulder. The stability of the elbow is considerably improved by this operation.

The final results in these cases are distinctly promising. Pronation and supination are lost, but, at a later date, if the ankylosis is firm, operation may be undertaken with a view of restoring this movement.

Flail Wrist. This is so rare that one need only say, ankylosis should be performed if thereby function is likely to benefit.

AMPUTATIONS

BY

Major R. C. ELMSLIE

AMPUTATIONS

In certain amputations the stump left is itself useful without any artificial limb or appliance being fitted. For example, a patient who has lost his foot, a Syme amputation having been carried out, can walk on the stump as comfortably as upon his own foot, the only difficulty being the shortening of the limb, and partial amputations of the hand in many cases leave a remnant that is more useful than any artificial appliance; but these cases are the exception and for most amputations the fitting of an artificial limb will be necessary. In military surgery we may take it for granted that an artificial limb of the best type available will be supplied, therefore, in deciding upon the level of an amputation and the method by which it should be carried out, we should bear in mind first the possible functional utility of the stump itself, and second the way in which an artificial limb will be adapted to it. It is therefore advisable for surgeons who are carrying out amputations to know something of the method of fitting an artificial limb.

ARTIFICIAL LEGS

An artificial leg has to transmit the weight of the body to the ground when the patient is standing, it must move as nearly as possible as the natural leg moves when the patient walks, and at each step it must be automatically stable when the patient's weight falls upon it, and have no tendency to double up or collapse. We may take it for granted that externally the artificial leg will be made to imitate, more or less exactly, the shape of the natural leg. The chief points for description then in the artificial leg are, first, the method of transmitting the weight; second, the mode of attachment of the limb to the body; and third, the mechanism of the joints of the knee and the ankle.

Bearing Points. Only in special amputations can the whole weight of the body be transmitted to an artificial limb or to the ground through the surface at the termination of the stump (*end bearing*); more often a proportion of the weight can be taken in this way (*partial end bearing*). In most cases the greater part of the weight must be transmitted to the artificial limb by pressure upon the bony points around the joint next above the site of the amputation, that is around the knee-joint in cases of amputation through the leg (*tibial bearing*), and around the hip-joint in cases of amputation through the thigh (*ischial bearing*).

Complete end bearing is most valuable when it can be secured; Syme's amputation gives an almost perfect end-bearing stump, and the patient with this amputation has the great advantage that he is to some extent independent of his artificial limb. In the morning before dressing he can walk about his room on his stump, whereas the patient with an amputation at only a slightly higher level must use crutches, or hop until he has put on his artificial limb. The factors in a stump which favour end bearing are (1) a division of the bone through cancellous tissue; (2) a covering of thick fibrous or areolar tissue over the end of the bone; and (3) a skin flap from a part which normally bears weight. In Syme's amputation, all these factors are present. In amputations through the knee, or through the condyles of the femur, they are also present and end bearing may be complete. Many other amputations will carry a considerable proportion of the weight upon the extremity of the stump, particularly those through the upper third of the tibia and the lower third of the femur. Recent experience in the use of plaster-of-Paris peg legs has shown that most amputation stumps which are covered with a single long flap containing muscle are capable of bearing weight upon their extremity in a bucket made of plaster of Paris and moulded accurately to the surface of the stump so that there is no friction.

In all amputations through the tibia above the level of a Syme the weight should be borne by the close fitting of the bucket around the internal tuberosity and tubercle of the tibia and the lower margin of the patella. The bucket must be fitted rather more loosely on the outer side as the head of the fibula is unable to stand much pressure. Some limb-makers prefer to take the weight in this case through the leather thigh piece, either by compressing the thigh tightly in this fitting, or by extending the bucket up to the level of the tuberosity of the ischium and so gaining an ischial bearing. This method of fitting renders the limb unnecessarily clumsy and heavy, and constricts the thigh muscles in a way that interferes with their use. It is sometimes adopted by limb-makers because they lack the skill necessary to shape a bucket accurately to fit the tibia and patella; it should be reserved for a few special cases in which the head of the tibia is intolerant of pressure.

In amputations through the thigh the weight is borne mainly by a close fitting of the top of the bucket under the tuberosity of the ischium; practically the edge of the bucket is fitted in exactly the same way as is the ring of a Thomas splint. The tuberosity of the ischium should rest either upon the edge of the bucket or upon a rounded ledge in its interior; the rest of the bucket should enclose the stump, fitting it very accurately to within an inch of its extremity. If this circumferential fitting is very close, a certain amount of weight is borne by the

friction between the thigh and the bucket ; it is, however, not usually practical to take a very large proportion of the weight in this way, because the result of the friction is to draw the skin upwards so that it is stretched over the end of the stump. If the scar is linear, mobile, and situated anteriorly, posteriorly, or laterally, a considerable amount of tension upon the skin can be borne, but if there is a terminal scar, particularly if it is extensive, thin, or adherent, this tension is very likely to produce ulceration.

The Shape of the Thigh Bucket. As already mentioned, the thigh bucket should fit the entire stump accurately, and it should do this without deforming the shape of the stump. It is not unusual to find that the interior of an artificial limb bucket is nearly circular, a shape which is hardly ever found in a section through the thigh. Looked at from the front the inner side of the bucket should be slightly concave, corresponding with the natural concavity in the adductor region, but exaggerating this slightly. Looked at from the side the posterior surface of the bucket should also be concave, again slightly exaggerating the normal concavity in this situation. The reason for exaggerating these concavities is that by so doing the ledge upon which the tuberosity of the ischium rests is emphasized, and at the same time rounded. The upper border of the bucket is cut away a little on the inner side in order to avoid pressure upon the perineum. From this, its lowest point, the edge of the bucket rises slightly posteriorly, where it rests against the tuberosity of the ischium. The anterior edge of the bucket slopes upwards and outwards so that on the outer side it reaches as high as the great trochanter, against which it should fit very accurately. As a rule the whole thigh piece of a wooden leg is made with the bucket out of a single piece of wood. In order to make adjustments for length, however, the thigh piece may be cut across transversely, the upper section or bucket being united to the lower section or knee piece by dovetailing.

Attachment of the Artificial Limb. The simplest method of attaching an artificial limb for an amputation through the thigh is by means of a brace passing over both shoulders and attached to the upper margin of the bucket in front and behind. The great objection to this simple brace is that any movement of the limb at the hip-joint will put tension upon the brace on one aspect of the body, and relax the tension upon the opposite aspect ; either the brace must become very tight on one aspect, or it must slip backwards and forwards on the shoulders ; this is particularly uncomfortable when the patient sits down. The same criticism applies to a second method of attaching the limb, namely, to a waist belt or pelvic belt, by straps attached to the margins of the bucket. The form of suspension now practically invariably used is that

which was introduced into this country in the American leg; in this the braces which pass over the shoulders terminate below in two loops formed of stout leather thongs, the ends of each loop being attached to the front and back of the braces. The loops pass below through the thigh piece, in which they run under a pair of pulleys which form part of the knee mechanism. When the limb swings the movement comes upon these leather thongs which roll under the pulleys and no friction upon the shoulders occurs; this method of suspension, in addition to the added comfort resulting from the disappearance of friction, enables us also to utilize the suspensory mechanism to assist in producing extension of the artificial knee-joint in the manner presently to be described. When the amputation stump is very short it tends to slip out of the bucket and some additional method of attachment is necessary, this usually consisting of a steel pelvic band, which encircles two-thirds of the circumference of the pelvis just below the anterior superior spines of the ilium, and is completed in front by a leather strap and buckle. This pelvic band is hinged to a vertical steel which is securely fixed to the outer side of the thigh bucket.

Mechanism of the Knee-joint. In order that the gait with an artificial leg may be as natural as possible the knee-joint must be freely mobile. It is well known that it is possible for a patient who has completely lost the quadriceps extensor cruris muscle to walk securely upon a level surface: he does this by allowing the knee to hyperextend, the joint locking in this position because its centre of movement is behind the line through which the weight of the body passes, and because the posterior ligaments and crucial ligaments prevent the knee extending further. The first principle of securing stability in an artificial leg is to centre the movement of the knee well back and to allow the joint to hyperextend. It is quite possible to arrange a suitable knee-joint with no other mechanism than this. In such a simple joint the patient swings the leg forward by a pendulum action: he allows the weight to come upon the leg as soon as the knee has extended fully, and all that is necessary is to make sure that the pressure will be exerted in such a way as to force the knee into the hyperextended position; the latter point is secure by attaching the foot in such a way that it will not dorsiflex as far as the right angle, that is, it is set slightly in the position of a talipes equinus. The strain thrown upon the knee-joint by the production of hyperextension when a patient has a slight degree of talipes equinus is well known to orthopædic surgeons. This simple pendulum action of the knee has two objections: first, that it is somewhat slow, and so necessitates a rather laboured gait; and second, that the patient often feels a sense of insecurity due to the fact that there is no active force which can be used to extend the joint if the swing does not extend it

fully. For these reasons it is customary to add one or two additional methods of securing extension of the knee; the simplest of these is the addition of an accumulator or spring as an extending force. A simple accumulator of elastic may be attached to the front of the thigh and the

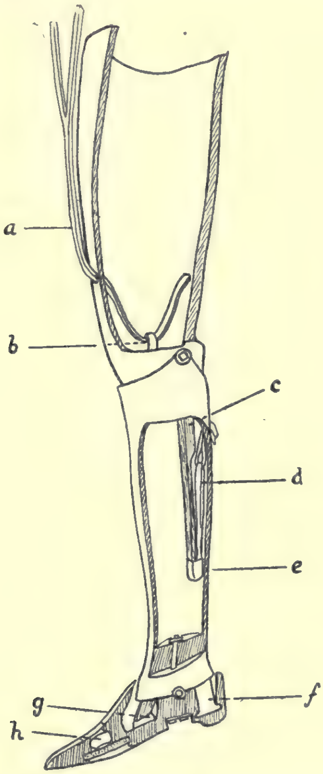


FIG. 184.—Diagram of an artificial leg for amputation above the knee. The leather thong *a* passes under a pulley at *b*; tension upon this thong extends the knee-joint. A wooden rod *c* is hinged to the thigh piece at its upper end behind the bolt which forms the knee-joint; its lower end rests in a leather cup *e*, which is suspended by an elastic *d*, which is attached above by a leather thong tied through two holes in the top of the leg piece. When the knee is flexed, tension is placed upon *d*, and the resultant force tends to extend the knee. In the ankle-joint are two rubber buffers, *f* and *g*; the joint only moves to the extent allowed by the compression of these. The toe-joint is formed by a hinge of leather seen below; *h* is a small rubber buffer which is compressed when the toe is dorsiflexed.

front of the leg, so that this has a constant tendency to extend the knee. The objection to it is that the force is still in action when the patient sits down, and if the spring is strong he may find that the moment that he raises the foot from the floor the leg tends to spring forward. It is better to use an internal spring which is so centred that it will only

extend the knee from a position of flexion up to the right angle, having its action abolished or reversed at this point. The form most used is that shown in Fig. 184. The second method used for extending the knee is by means of the sling; the pulleys under which the thongs attached to the slings pass form part of that section of the knee-joint which is continuous with the leg piece, and they are situated in front of the axis of the joint. When tension is put upon the thongs a leverage is exerted which tends to extend the knee. Tension may be put upon the sling by the patient's own action, that is by elevating the shoulders, but even without this voluntary action the weight of the limb produces tension upon the sling whenever the foot is off the ground, and for this reason directly the foot leaves the ground a force comes into action which helps to extend the knee. To sum up then, stability in the knee-joint is secured by centring the axis of the joint well backward, by assisting extension of the knee by means of a spring and by the action of the sling, and the knee is forced into a hyperextended position by fixing the foot in slight equinus.

Mechanism of the Ankle-joint. The ankle-joint moves comparatively little in normal walking upon level ground: its total range of angular movement is not more than 20° to 30°. The maximum dorsiflexion being only just beyond the right angle, the maximum plantar flexion about 15° to 20° beyond the right angle in the other direction. It is quite possible to fix the artificial ankle-joint so that it is immobile and even so to get a very natural walk. It is usual, however, to allow a slight rocking movement of the joint, the movement being limited by the compression of anterior and posterior rubber buffers placed between the foot and leg. As already mentioned, in order to secure stability of the knee, dorsiflexion in the artificial ankle-joint must not be allowed to reach the right angle; practically the extreme of dorsiflexion is that position which the foot assumes when the patient stands upright in an ordinary boot with such a heel as he usually wears and with the knee pressed well back; from this extreme position in one direction, further plantar flexion of 20° is permitted. Many other designs of ankle movement are in existence including some in which a lateral movement is allowed, and some in which a tendon attached from the back of the knee to the heel secures plantar flexion of the foot when the knee is extended and a dorsiflexion when the knee is flexed; all these variations of joint have been superseded by the simple one already described.

Limb for Amputation through the Knee. When the leg has been amputated through the knee the lower end of the stump is larger than the part immediately higher up; for this reason it is impossible to slip the stump into an entire wooden bucket, either the bucket must be made

of leather which laces up the front of the thigh, or, if it is of wood, the lower part must be cut away in front and replaced with a lacing piece of leather. The leg must be attached to the thigh piece by lateral steels and the knee-extending mechanism must be placed on the outside; these alterations render the limb clumsier and heavier than that made for the ordinary thigh amputation.

FIG. 185.—Artificial leg for below-knee amputation. The leg bucket is attached to the thigh corset of leather by lateral steels with simple hinge joints, which are displaced backwards by curving the lower ends of the thigh steels, so as to correspond in position as accurately as possible with the natural knee-joint. A leather lace behind the knee limits extension (popliteal check cord). The ankle-joint is the same as in the leg for thigh amputations.

Artificial Limb for Amputation through the Leg. As already mentioned, in amputations below the knee the bucket is fitted closely around the head of the tibia and below the patella, its upper margin must be cut down well at the back in order that the hamstring tendons may not be compressed when the joint is flexed. As the patient possesses a natural knee-joint, a mechanism to extend the joint is unnecessary except in the case of very short stumps; in these a strap attached to the

sling may be fixed to the front of the leg bucket. It is also unnecessary to limit dorsiflexion of the foot to the right angle; by allowing this movement to extend until the angle between the leg and foot is about 80° the patient's comfort will be increased and the strain upon his knee-joint diminished. It is customary to attach the leg by fitting lateral steels jointed at the knee, the thigh sections of which are fixed to a leather corset which encloses the thigh; this is very secure but somewhat heavy, and it can be dispensed with in many patients who have good stumps below the knee. Limb-makers find a difficulty in fitting the simpler method of attachment which consists of a small leather collar encircling the thigh just above the knee to which the leg bucket is attached by lateral straps of leather. The reason for their difficulty is that they fix the foot in the equinus position and that this throws a strain upon the knee, making it hyperextend. The patient's natural knee-joint cannot stand this strain, and it is counteracted by tying the back of the thigh corset to the back of the leg bucket by a popliteal check cord. If the foot is allowed to dorsiflex the necessity for this check cord disappears and the thigh corset and lateral steels can be dispensed with.

Artificial Limb for Syme's Amputation. A Syme amputation leaves two inches or more between the end of the stump and the ground, there is, therefore, ample room for the introduction of an artificial ankle-joint of the same pattern as that already described. All that is necessary, therefore, is to enclose the leg from the knee downwards in a well-fitted leather sheath to the lower end of which an artificial ankle and foot are attached by steels.

LEVELS OF AMPUTATION IN THE LOWER LIMB

Amputation of the Foot. The normal foot has three chief bearing points, the heel and the heads of the first and fifth metatarsal bones. In walking the heel meets the ground first at the beginning of the step, later the weight is rolled forward on to the anterior bearing points; the toes are used chiefly as a means of balancing just as the foot leaves the ground. Amputation of any individual toe leaves so small a disability that it may be freely performed for any injury or painful condition, even the big toe may be thus sacrificed. When more than one toe has to be amputated the effect will depend upon the toes removed, but it may be said generally that a second toe may be sacrificed freely; if three or four have to be amputated the patient will probably be better off if all the toes are removed at once. In amputations of the toes, as in all foot amputations, the scar should be kept in a dorsal position and the stump covered entirely with sound skin; a wound which has healed by granulation upon a foot stump is very likely to give trouble.

Lisfranc's amputation and similar amputations at the tarso-metatarsal junction leave a good stump provided that the scar is dorsal and sound ; for this amputation and for amputations of the toes no artificial foot is necessary, the patient can wear an ordinary boot in which the toe is filled or in which the front part of the upper is stiffened.

Chopart's operation is not a good one, the tendons of the tibialis anticus, long extensors and peronei lose their anterior attachment, and the stump is pulled by the tendo Achillis and tibialis posticus into an

FIG. 186.—Chopart's amputation on the left, with the stump plantar flexed and inverted by contraction of the tendo Achillis and tibialis posticus. Syme's amputation on the right; the flap has been badly cut, so that there is no good flat surface at the extremity for end bearing. Re-amputation was necessary on both sides.

equino-varus deformity, so that the patient instead of walking on the under surface of the heel walks upon the outer part of the anterior extremity of the stump. In most cases of Chopart's amputation an artificial foot cannot be fitted and re-amputation is required. When, however, the tendons of the tibialis anticus and peronei have been reattached and the stump kept in a good position, the result may be satisfactory. Pirogoff's amputation and similar amputations, in which a part of the os calcis is retained in the flap, have no advantage over Syme's amputation when an artificial foot is to be worn ; these amputations are designed to avoid shortening and to keep the prominence of the malleoli, so that a simple boot can be worn instead of a more elaborate artificial foot. From this point of view they have advantages for the poor

hospital patient who may find it impossible to get an artificial foot, but if such a foot is to be obtained the preservation of length is a disadvantage because it prevents the introduction of a good artificial ankle-joint. In addition in military surgery, in which the risk of sepsis must always be present, the preservation of a piece of bone in the flap and its fixation over the cut end of the tibia and fibula is a danger, for if necrosis occurs, or if the bone does not unite, a re-amputation will probably be necessary.

Syme's amputation is undoubtedly the best amputation in the lower limb. It is objected to by some limb-makers because it is more difficult to fit than is a straightforward amputation through the middle of the leg, but this is much more than counterbalanced by the facts that a patient with a good Syme amputation can walk ten to fifteen miles, run, jump, and play such games as tennis and golf almost without his disability being noticed. The fact that in addition he is to some extent independent of the artificial foot inasmuch as he can get about by walking upon the end of the stump has already been mentioned.

FIG. 187.—The elliptical incision for Syme's amputation.

In claiming such success for a Syme amputation we must make the proviso that it is a good one, there must be two inches between the end of the stump and the ground, the bone must have a clean flat under-surface and must be covered with a closely-fitting flap, the skin of which is quite sound, and which has no spots that are tender upon pressure. The common faults in a Syme amputation are that the bone is cut too long, the flap is too large so that it leaves a flabby end to the stump, and the plantar nerves are often left in the flap which may for this reason be acutely sensitive. The classical incision leaves too large a flap ; the best incision is an elliptical one, the angle between the two parts of the classical incision being abolished by taking the anterior incision up to a higher level and by carrying the lower incision to within $\frac{3}{4}$ in. of the point of the heel. The tibia and fibula should be divided a good $\frac{1}{2}$ in. above the level of the articular surface of the ankle-joint, the nerves should be dissected well back and the main posterior tibial nerve crushed, ligatured, and divided above the level of the malleoli. It is most important that the heel flap should have a good blood supply, for this reason great care must be taken in removing the astragalus and os calcis to cut very close to the bone and thus avoid injury to the vessels. If the blood supply to the flap is insufficient its margins may slough and a re-amputation through the leg will probably be necessary. In cases in

which the posterior tibial artery has already been ligatured, or in which there is much scarring of the lower part of the leg, sloughing of the flap is very likely to occur. These conditions and scarring of the heel should be held to contra-indicate a Syme amputation, an amputation through the middle of the leg being performed instead. Suppuration of a Syme amputation is a very serious accident ; if any necrosis of the bone occurs the stump will almost certainly not bear weight upon its end and the patient must either wear a clumsy limb with bearing

FIG. 188.—A good end bearing Syme's amputation, with $2\frac{1}{4}$ in. clearance between the end of the stump and the ground.

upon the head of the tibia, or he must have a re-amputation. For this reason it is most important that a Syme amputation should be postponed if there is a risk of its becoming septic.

In all amputations a distinction must be made between an operation carried out under conditions in which asepsis can be secured, and one which is performed through a septic field. The idea of settling upon good levels of amputations is to secure that the patient will have a stump upon which a good artificial limb can be fitted. When an amputation is performed in a septic field we cannot be certain that the operation will be final. In many, in fact in most, cases a re-amputation is necessary, so that the stump is shortened ; for this reason the surgeon should only choose these desirable levels of amputation in cases in which he can promise asepsis ; in all others his rule should be to preserve as much of the limb as possible and to leave the subsequent arrangement of a

good stump for a later stage. Thus in a wound of the anterior part of the foot in which amputation is decided upon, Syme's amputation is only indicated if asepsis can be secured, or if no amputation at a lower level is possible. If at the time of the amputation there is œdema around the ankle-joint an infection of the amputation wound is very probable. It would be better to amputate through the tarsus leaving an open wound

FIG. 189.—Syme's amputation in which a part of the flap has sloughed. The leg was much scarred and the posterior tibial artery had been tied. It was noticed at the time of the amputation that the flap did not bleed freely. Re-amputation through the middle of the leg was necessary.

for perfect drainage, then at a later stage when sepsis has subsided, and perhaps a simple granulating ulcer remains, a Syme amputation can be performed in an aseptic field. If the wound is so close to the ankle that no amputation below the malleoli is possible, it may be advisable to cut a Syme flap and amputate through the ankle-joint, leaving the lower end of the tibia and fibula untouched and packing the wound without suturing. After sepsis has subsided and the wound is granulating the tibia and fibula can be divided and the stump sutured as in performing

a secondary suture. Drainage of a Syme amputation by puncturing the heel flap has been advocated ; this is a mistake, for it leaves a scar in the middle of the chief bearing surface which may considerably interfere with the comfortable fitting of an end bearing limb.

Amputations through the Leg. Up to a certain point the longer the stump left below the knee the better, but a very long stump has certain disadvantages without corresponding good points. In these long stumps the skin over the end has often a poor circulation and ulceration is frequent. In addition the leg bucket must be made wide enough to enclose the stump, with the result that the ankle of the artificial limb has

FIG. 190.—Skiagram of an amputation through the leg in which the fibula is longer than the tibia. Removal of part of the fibula was necessary before a limb could be fitted.

to be made thicker than that of the natural leg ; a stump which contains seven inches of the tibia measured from the joint line is the best. The best flap in the leg is a single one taken from the posterior or postero-external surface and leaving an antero-internal scar. Alternatively, however, an anterior or antero-internal flap may be taken. If possible, the flap should contain muscle. The length of the stump should not be shortened in order to obtain an ideal flap. A frequent mistake in amputation through the leg is to cut the flaps too long, they should just cover the bone snugly without tension being necessary but without leaving any flabby end of the stump. When the flaps have been cut long this

flabby termination of the stump has often a poor circulation and tends to ulcerate.

The crest of the tibia should be rounded with the saw or with a file, and the fibula should be cut slightly shorter than the tibia. A long fibula is a great inconvenience in fitting an artificial limb. It is worth while preserving even very short stumps below the knee. The test of utility of such a stump is to flex the knee to a right angle, and then to try whether a finger can be hooked around the stump and thus secure a hold. It will be found that in most cases a stump containing only two inches of tibia measured from the joint margin answers to this test. In these short stumps there is a tendency for the fibula to tilt away from the tibia and project; in this case it is a good plan to remove the whole of the fibula. In this way a piece of bone is removed which stands pressure badly and at the same time the bulk of the stump is diminished, so that a flap which would otherwise be too small may suffice. The preservation of these short stumps below the knee is of very great importance, because the patient having his own knee-joint is able to walk up and down stairs and on irregular ground in a way that would be impossible if the amputation were through the thigh. For this reason it may be desirable to leave such a short stump to heal by granulation, a thin adherent scar resulting. We may then try to fit an artificial limb, always being able to re-amputate above the knee or to fit the leg upon the flexed knee in case of failure.

Many leg stumps become flexed at the knee-joint, extension being impossible; this is due to a fault in early treatment: all leg amputations should be kept upon a back splint until the wound is healed. When flexion is established it can usually be corrected by daily stretching with the hand and by the use of a posterior splint. In some cases, however, operative treatment is required; it will then be found that the obstruction to extension is due to a contraction of the attachment of the gastrocnemius and of the posterior ligament of the knee-joint; division of this as well as of the hamstring tendons and the ilio-tibial band will be necessary before the knee can be straightened. The operation should be carried out through two longitudinal incisions on either side of the posterior aspect of the joint. Care should be taken to preserve the popliteal vessels, as if these have to be ligatured, sloughing at the end of the stump is very likely to ensue. If every effort to extend the knee fails, the joint may be left flexed to a right angle and an artificial leg fitted as for a knee-joint amputation. This is, however, a confession of failure, leaving the man to lose the advantage that he should have gained by the preservation of the knee-joint. In amputations through the leg in which the knee is ankylosed re-amputation should be performed through the condyles of the femur.

Amputation through the Knee. From the surgical point of view this operation has objections. When sepsis is present it is a very risky procedure, and even under good conditions it requires very large flaps, which can seldom be secured in cases in which the knee-joint cannot be preserved. In order that a good artificial limb may be fitted, the end of the femur must be uninjured and it must be covered with healthy skin, the scar lying over the popliteal aspect of the bone ; therefore, unless large clean flaps can be obtained, it will be better to amputate at a higher level. It has already been mentioned that the artificial limb for a knee-joint amputation is somewhat clumsy and heavy, but an amputation through the condyles of the femur at the Stokes-Gritti level is at least

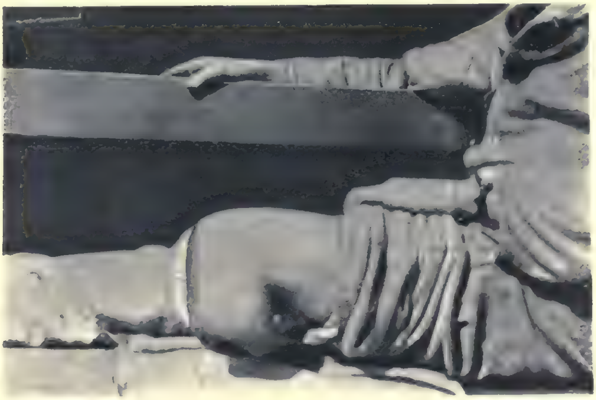


FIG. 191.—Amputation through the upper part of the leg, with the stump flexed at the knee to a right angle.

as easy to fit and enables the patient to walk as well. It seems, therefore, that this amputation might be substituted for that through the joint.

Amputation through the Thigh. The best amputation above the knee is that in which the bone is divided through the upper part of the supracondylar ridges, the bone being covered with an anterior flap. The Stokes-Gritti operation at this level, in which the superficial half of the patella is preserved and pinned over the cut end of the bone, is a very good one, provided that asepsis can be secured. If the wound suppurates the use of the patella is a danger, for it may fail to unite to the femur or necrosis may occur and the removal of the necrosed bone be very difficult ; therefore, as a rule, the patella should be removed, but the fibrous tissue around it should be retained and stitched over the end of the bone.

Some artificial limb makers object to this amputation because the length of the stump interferes with their knee mechanism ; they can, however, get over this difficulty, and the good leverage given by the

long stump and its ability to take end bearing more than compensates for any disadvantage.

Above this level, the only rule for thigh amputations is that every inch of bone must be preserved. With this end in view flaps should be cut from wherever skin is available, always avoiding the inclusion of scars in the flap. If there is any choice a single long flap is the best, and this is best cut from the outer side, so that the scar becomes internal where it is least liable to pressure. In thigh amputations there is a great tendency for the muscles to retract leaving the end of the bone prominent under the skin, therefore the flaps should be cut deeply and the muscles

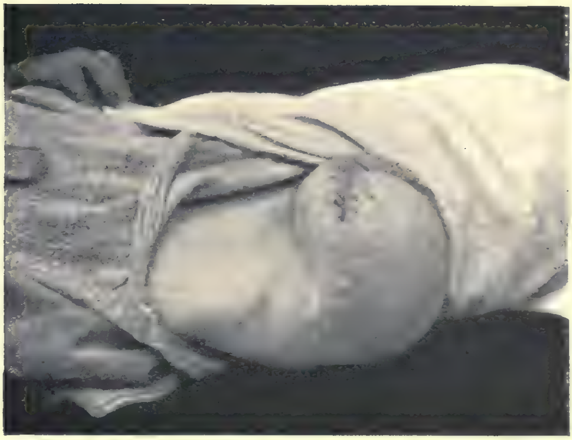
FIG. 192.—Test for flexion deformity of the hip. The patient lies on his back on a hard couch; the sound hip is flexed completely, any lordosis being thus abolished. The full degree of flexion deformity in the affected hip can thus be seen.

sutured over the bone ; as in amputations through the leg flaps should not be too long and should be sutured closely but without tension.

There is a great tendency for a thigh stump to become abducted and flexed at the hip-joint ; this will interfere seriously with the fitting of an artificial limb. In many cases this deformity has arisen because a septic stump has been left to ulcerate and granulate for a long time between the primary amputation and the final trimming which results in healing. The danger of it arising is a strong argument for a line of surgical treatment which will accelerate healing of the stump. The position assumed by the stump when the patient sits in bed or on a chair is an important factor in causing the deformity ; in all thigh amputations this contraction at the hip should be guarded against from

the first by daily stretching and manipulation. The use of the stump in a temporary peg leg will also prevent this contracture arising.

When the patient stands he can hide a considerable degree of abduction and flexion deformity by tilting the pelvis and hollowing the lumbar spine ; it is necessary, therefore, to test for this deformity by a routine



Figs. 193 and 194.—A very short thigh stump, in the extended and flexed positions. When the hip is flexed the stump almost disappears ; it is too short to get a secure hold in the bucket.

method. The patient should lie upon a hard table, without pillows and with the pelvis straight, then, ignoring the stump, the healthy hip is flexed fully until the thigh is in contact with the abdomen ; in this position lordosis is abolished and the full degree of flexion deformity can be estimated. It will often be found that the patient can extend the

hip if abduction is permitted, therefore the level of the anterior superior spine must be carefully noted during the test.

When the deformity is once established it must be overcome by daily stretching ; a routine method is necessary for this. The patient should lie on a hard table with the sound hip flexed, a strap may then be passed over the front of the stump and through two slots in the table, being attached below to a pedal ; the masseur by pressing on the pedal with his foot forcibly extends the hip, both his hands being free to manipulate the stump and thus to overcome the abduction. A second method, which is not so good, is to place the patient upon his face and to hyperextend the hip in this position. Occasionally this deformity will require operation ; it will then be found necessary to divide the tensor fasciæ femoris, sartorius, the rectus femoris, the muscles attached to the great trochanter and digital fossa, the ileo-psoas, and the anterior part of the capsule of the hip-joint : these may all be divided through an incision extending for about 4 in. vertically downwards from the anterior superior spine.

In order that a thigh stump may secure a proper hold in the bucket of an artificial limb, it must measure at least 2 in. on its inner side below the perineum ; this is equivalent to about 5 in. of femur measured from the tip of the great trochanter. If the stump is shorter than this it will slip out of the bucket when the patient swings the leg. In these very short stumps there is a great tendency to flexion and abduction deformity, and because little leverage can be obtained the correction of this deformity is specially difficult. When the stump is too short to secure a proper hold in the bucket, it must be kept flexed to a right angle and entirely enclosed in a pelvic fitting, an artificial hip-joint being attached. The artificial limb is then similar to that used for a hip-joint amputation. It must not be assumed from this that these short amputations should be substituted by amputations through the hip-joint, the additional shock involved in the latter amputation must always be remembered. But occasionally such a short stump remains infected and healing is delayed. It may then be advisable to save the patient from a further prolonged illness by excising the remains of the femur and converting the amputation into one through the joint.

Amputations through the Hip-joint. Amputations through the hip-joint are fitted by enclosing the whole of the stump in a leather case which is secured by a steel pelvic band ; to this case the artificial limb is fitted by an external hip-joint. The best hip-joint amputation is that carried out through a racket incision with the vertical part in front over the vessels. The scar should cross the buttock well away from the perineum and from the tuberosity of the ischium ; the muscles should be preserved in the flap so that a good pad is left over the region of the

acetabulum ; the nerves, however, particularly the great and small sciatic and the anterior crural, should be cut very short. The Furneaux Jordan operation should not be performed; it leaves a flabby stump which is incapable of controlling an artificial limb, and which is only an embarrassment because it must be folded up and enclosed in the leather case.

ARTIFICIAL ARMS

The use of an artificial leg is simple, it has to bear the patient's weight and to carry out the movements of walking. An artificial arm is a very different thing, it is really a tool used to convey movements from the stump to anything which the patient holds in it. It cannot pretend really to replace the natural arm ; unless the patient realizes this and understands that he is being given an appliance for use for particular purposes, he will invariably be disappointed.

An artificial arm must be secured to the stump in such a way that traction will not pull it off. It should also resist pressure in the opposite direction, and should be so fitted that torsion does not tend to displace it. The resistence to traction is furnished by three points :

1. In amputations at the wrist a fitting can be secured above the styloid processes of the radius and ulna.
2. In amputations above this level the arm section can secure a hold around the humerus above the condyles.
3. In amputations through the arm the limb must be secured by a harness attached over the shoulder and passing beneath the opposite axilla.

The resistance to pressure so that the stump is not forced into the bucket is also secured in three ways :

1. In amputations below the elbow the stump tapers from above downwards, so that if the bucket fits the forearm accurately the enlargement of the muscles below the elbow prevents upward pressure.
2. In most cases pressure will come upon the forearm with the elbow flexed ; it is then resisted by the fitting around the humerus, which is attached to the forearm section by lateral steel joints.
3. In amputations above the elbow, direct upward pressure can only be resisted by the inner side of the arm bucket meeting the axillary folds.

The resistance to torsion of the artificial arm practically only exists when the amputation is below the elbow. The transverse diameter of the forearm is greater than the antero-posterior diameter, therefore if

the bucket fits accurately it cannot be twisted upon the forearm; the steel elbow-joints also resist torsion. In amputation above the elbow the stump is cylindrical, so that the only resistance to torsion is that given by the mode of fitting of the shoulder harness; unless a very cumbersome harness is used this resistance is very small.

Many varieties of artificial arms for amputation above the elbow are in use; all of them, however, contain the same essential parts, namely:

1. The harness.
2. The arm bucket.
3. The elbow-joint.
4. The forearm section.
5. The hand or appliances substituted for it.

The Harness. The best harness is one which consists of two or three straps attached to the top of the bucket and joined together on the shoulder to a strap which passes under the opposite axilla. This is all that is necessary for any except very short stumps. For the latter it may be advisable to fit a leather plate over the shoulder and attach the arm bucket to this by a steel joint on the upper and outer side. An important point about the harness is that it should be sufficiently simple to allow the bearer to put on his arm without assistance.

The Arm Bucket. The arm bucket is usually made in the form of a sheath of leather, but other materials such as celluloid, wood, &c., may be used instead. It fits the stump closely up to the level of the axillary fold on the inner side and well over the deltoid on the outer side; below it may be closed in around the end of the stump, or may extend beyond it down to the level of the elbow-joint. The bucket may be a complete cylinder or may be laced down the front.

The Elbow-joint and Forearm. The elbow-joint is formed by lateral steels with hinged joints, or by means of a central pin through the whole limb. It must have a ratchet which enables the joint to be fixed at several different angular positions. The side steels below the elbow are fixed to a leather, metal or wooden forearm piece which terminates below in a wrist-plate to which the hand, or the implement used instead of it, is either screwed or attached by some sort of bayonet joint.

In a worker's arm the elbow-joint and forearm are usually detachable, so that they can be removed entirely and a hook or other appliance fixed directly to the arm bucket. In a mechanical arm the bucket, elbow, and forearm are fixed together and cannot be taken apart, the only detachable part being the hand, which can be unscrewed from the wrist-plate and replaced by other appliances.

Certain movements of the shoulder and chest can be utilized to actuate the artificial arm. For example, a Bowden wire can be fixed across the

back of the shoulders, the sheath being attached to a loop passing around one shoulder and the wire to a similar loop around the other shoulder. A forward movement of the shoulders will then pull upon the wire, and this pull can be utilized to flex the artificial elbow-joint. Four different pulls may be thus utilized, obtained by

(1) Bringing the shoulders forward ;
(2) Expanding the chest ;
(3) Elevation and depression of the shoulder ;
(4) Abduction of the stump at the shoulder.

The actual method of conveying these movements to the artificial arm varies greatly in the various types of limb that are in use, as do also the purposes for which the pulls thus exerted are employed. Generally it may be stated that these movements may be used for

(1) Flexing the artificial elbow-joint ;
(2) Engaging or disengaging the elbow lock ;
(3) Working the fingers and thumb of a mechanical hand or of a grip used instead of the hand. In some of these the pull opens the hand grip, which is closed by a spring ; in others the pull actually opens or closes the fingers by a leverage action.

In the Carnes arm, which is fitted with an automatic pronation movement, abduction of the shoulder is used to disengage this and to throw it out of action.

The Wrist-plate and Hand. The mechanical arm usually ends in a flat wrist-plate into which the hand, or hook, or other appliance screws. The worker's arm ends more often in a simple tubular socket into which the hand or other appliance screws. Instead of a screw, a snap catch may be used; it is quicker in action, but often less secure. Many varieties of snap catch are in use, and for the sake of securing interchangeability it is customary to insist that if a snap catch is used an adaptor should be fitted containing the standard screw thread, so that appliances which are made with this thread can be used.

Very many varieties of hands are in use, from the simplest 'dummy' hand to elaborate mechanical hands. Similarly the other appliances which may be used instead of a hand number hundreds, some are intended for general utility, others are adapted to special work. The actual details of the many varieties of artificial arms and of the appliances used with them are therefore very complicated. Fortunately it is unnecessary to describe them, because they have practically no influence upon the level of choice of an amputation of the arm or upon the method of performing the amputation.

Cinematization of stumps of the upper limb, with the fitting of

artificial arms which are actuated by the muscles of the remaining segments of the limb, may in the future prove to be of considerable utility. These methods are described in a separate section.

ARTIFICIAL LIMB FOR AMPUTATION THROUGH THE FOREARM

When a forearm stump of good length is left, normal elbow movements remain. The artificial limb is fitted by adapting a bucket closely to the forearm, and attaching this bucket to the arm by lateral steels jointed at the elbow with a leather corset around the arm. The steels and arm corset are fitted closely above the condyles of the humerus. Both the arm corset and the forearm bucket must be cut away well in front of the elbow so that they do not block flexion of this joint. The wrist-plate and hand are exactly similar to those used in above-elbow amputations.

In amputations through the upper third of the forearm there is a difficulty in fitting the artificial limb. This arises because when such a short stump is flexed at the elbow its antero-posterior diameter is increased by the contraction of the muscles arising from the condyles of the humerus, so that if the bucket fits in the extended position of the joint it is too tight when the joint is flexed. Further, the contraction of these muscles tends to push the bucket off the stump. Several devices have been used to get over this difficulty. The best of these is the Williams fitting, by means of which stumps containing from $2\frac{1}{2}$ to 4 in. of ulna can usually be fitted; when the stump contains only 2 in. of ulna it is generally impossible to fit it; it is then necessary to enclose the forearm stump in a soft leather case, and to fit an above-elbow arm with outside steel joints at the elbow and with an artificial elbow flexing movement.

The Williams method of fitting is as follows: The forearm bucket is of hard leather, and it fits accurately to the stump in a position of flexion at about 135°. To its upper margins are attached two lateral flaps of softer leather which lace together in front and behind. These are laced so that they secure a hold upon the supra-condylar ridges of the humerus; there are no steels at the elbow, the forearm being held on solely by these pieces of leather. An important item in the fitting is that the forearm bucket is attached in the position of flexion of the elbow to 135°. Full extension of the elbow is not allowed. By this method an artificial forearm can be fitted so securely that a heavy man may be pulled across the room by it.

THE LEVEL OF AMPUTATIONS IN THE UPPER LIMB

Partial Amputation of the Hand. In injuries of the hand conservative surgery is most important throughout. Practically always a hand in which two digits, or parts of two digits, remain is of greater use than

any artificial hand. For this reason early amputation of the hand or of any part of it should only be carried out when it is necessary as a life-saving device, or when the destruction is so complete that it is clear that no mobile digit can remain. Even then the immediate amputation should be strictly limited to the parts destroyed and no attempt should be made to carry out a formal amputation. The final decision as to the portion of the hand to be retained should be left until a late stage of treatment, when the wounds have healed and the function of the hand, as a whole, can be considered.

The loss of the thumb constitutes a very great disability, and it should only be sacrificed when it is hopeless to save any part of it, even in a mutilated state. Because of the importance of this digit in opposition to the fingers, a stiff thumb with all the joints ankylosed and all the long tendons lost is better than no thumb at all. If necessary, reparative operations can be performed ; an arthroplasty of the carpo-metacarpal joint may restore mobility, and suture or transplantation of tendons may be used as a method of regaining active movement. The stump left by amputation at the metacarpo-phalangeal joint is a useful one, because it has power of opposition, so that this section of the thumb should be kept unless the metacarpal bone and all the short muscles have been destroyed.

The question of sacrificing a damaged finger in order to improve the function of the hand will frequently arise. It must be answered by considering first whether any operative or other treatment will improve the utility of the finger, and, if this is impossible, by considering whether the finger in its damaged condition is interfering with the movements of the hand in general. In cases of general contraction of the fingers, the hand should never be sacrificed. Usually these cases have a double pathology, part of the contraction being due to an organic injury, part to a functional condition. Often some local pain accounts for much of the contracture and disability, even amputation may fail to relieve the pain, the patient desiring removal of yet another portion of the limb. Similarly amputation of a painful finger may fail to relieve the pain, unless the latter is due to some such cause as a fibrous ankylosis of one of the joints. In this case it might be possible to relieve the pain by an operation on the joint, or perhaps amputation of the finger may be justified by the fact that the finger is functionally useless and is interfering with its fellows.

In amputating individual fingers it is best to use a long palmar flap and so to leave the scar on the dorsal surface. Such part of the finger as is actively mobile should be kept and the long tendons should be sutured to the end of the stump. The digital nerves often become tender ; they should always be crushed and shortened in finger amputations. When the finger is being removed at the metacarpo-phalangeal joint, or at a

higher level, the method of amputating must depend upon the nature of the injury. If the metacarpal bone is intact the finger should be taken off through the joint, provided that there is sufficient skin to cover the stump, but if there is an ununited fracture of the metacarpal bone it will be better to remove the distal fragment. When the little finger is amputated in this way, the short muscles, if they are complete, should be sutured to the side of the extensor tendon of the ring finger.

When more than two fingers have been amputated it may sometimes be advisable to remove sections of the metacarpal bones, deliberately forming a lobster-claw hand similar to that seen in the congenital deformity. A hand in which the thumb and ring finger, or ring and little fingers have been preserved in this way may be very useful for almost every variety of work.

The preservation of a single digit is useful, for it is possible to attach an apparatus in which this digit can be opposed to a surface to give a grip and its point made to meet a projection, so that small articles can be held. When no digit remains a mobile stump containing some part of the carpus and metacarpus may be useful either in itself or as a means of actuating the grip of an artificial hand.

Amputations at the Wrist. In amputation through the wrist-joint the preservation of the inferior radio-ulnar joint leaves full pronation and supination, and the fact that the styloid processes remain enables us to fit the bucket of the artificial appliance around them and thus to hold it on securely; this amputation is therefore a good one. Some limb-makers object to it because it is difficult to fit and because the artificial hand must be made to project so that the limb is a little longer than the natural one. These, however, are small points compared with the gain in functional utility.

Amputations through the Forearm. Every possible inch of the forearm should be preserved because the long stump increases the leverage applied to the artificial arm, and because in a long stump containing more than half the length of the forearm a certain amount of pronation and supination will remain. The possibility of utilizing the forearm muscles by the operation of cinematization renders it advisable that these muscles should be preserved down to, and even beyond, the end of the bones, at least in the primary amputation. If at a later stage the muscles are found to be useless the stump can be trimmed up by a very simple operation. It does not matter much how the flaps are arranged in this, or in any amputations in the upper limb; it is seldom that scars give any trouble in the fitting of the artificial arm. When only a short portion of the forearm remains it is difficult to utilize this to move an artificial limb, because when the elbow is flexed the antero-posterior diameter of the upper part of the forearm is increased and a bucket

which fits tightly with the elbow extended is too tight when the elbow is flexed, or if it fits with the elbow flexed is too loose when the joint is extended. The usual result is that the artificial limb tends to be pushed off when the elbow is flexed; this difficulty arises when the stump of the ulna is less than four inches long, and when less than two inches of bone remains the stump disappears altogether in the flexed position and fitting is impossible. Two surgical procedures have been adopted to overcome this difficulty: the more drastic is to re-amputate the arm above the elbow, the less drastic is to excise the whole of the forearm muscles from their attachment to the condyles of the humerus. Neither of these procedures is necessary or advisable. It is possible to fit most of these stumps by the method adopted by Williams, and even if this is not possible, an artificial elbow can be introduced, the forearm stump being ignored. The retention of the elbow-joint allows of a secure fitting around the humerus, which resists traction and rotation in a way that is impossible with a stump above the elbow.

Amputations through the Elbow-joint. The difficulty in amputations through the elbow-joint is a surgical one, the condyles of the humerus are very wide and a long flap is necessary to cover them, such a flap can seldom be obtained even in suitable cases. The limb-fitters urge another objection, that the fitting of the stump is difficult and that an external artificial elbow-joint is necessary and is weaker than the type of joint fitted in an artificial arm for an amputation above the elbow. The fact already mentioned that a secure hold can be obtained above the condyles of the humerus is a sufficient advantage to counterbalance any difficulty in fitting, therefore an amputation through the elbow may be carried out when it is possible and when none of the forearm can be saved.

Amputations through the Arm. The only necessity in amputations through the arm is to save every possible inch of bone; here, as in the forearm, muscles should be preserved in view of their possible subsequent use. The large nerves in the arm lie in exposed positions and are particularly liable to develop painful neuromata, they should always be crushed, shortened, and ligatured in the way described below.

Amputations through the Shoulder. A very short arm stump is unable to transmit movement to the artificial arm, practically 2 in. of stump measured from the anterior axillary fold is necessary for this purpose. This fact, however, does not modify the method of amputation; everything possible should be preserved, whether the stump is likely to have useful mobility or not. Patients with very short arm stumps and those with amputations through the shoulder-joint seldom wear artificial arms except for show. If the upper end of the humerus is kept the symmetry of the shoulders is preserved, a considerable advantage to a patient who does not care to wear an artificial limb for which he can find no use.

PAINFUL AMPUTATION STUMPS

The usual cause of pain in an amputation stump is a neuroma upon one of the divided nerves. In every case the stump should be carefully palpated and the exact site of the pain localized ; in most of them a definite tender spot will be found over the enlarged end of one or other of the nerves. The smaller nerves, particularly those which are sensory, must not be ignored. It is not unusual to find that after the sciatic nerve or its branches have been shortened to cure pain in a thigh stump, the long saphenous nerve remains tender and requires treatment. Sometimes instead of a local tenderness over the nerve itself, a diffuse tenderness of a considerable area of the end of the stump will be found. Sometimes pain is independent of pressure and is referred to a definite area in the amputated limb, usually the area of distribution of one of the main nerves. The pathological cause of this painful condition is not always the same : in some cases there is a definite painful neuroma, the pain is usually then localized to this one spot and is brought on by pressure ; in others the neuroma is adherent in scar tissue and is dragged upon in every movement of the stump ; in others, again, new axis cylinders have grown out from the neuromata into the tissues around and thus produced a diffuse area of tenderness. The formation of a neuroma upon a divided nerve is inevitable ; the object of. the surgeon should be to confine the growth of axis cylinders to the limits of the neuroma itself and to see that this lies in a situation in which it does not tend to become adherent and is not liable to pressure.

The best method of limiting the neuroma is by first crushing the nerve with a heavy pair of pressure forceps, or with a crushing clamp ; this divides the axis cylinders, leaving the sheath intact. With a catgut ligature this sheath can then be closed and the nerve divided beyond the point crushed ; by this means the new axis cylinders are prevented from wandering in the surrounding tissue. If every nerve in an amputation is treated by this method, and is at the same time shortened so that it does not tend to become involved in the scar, painful stumps will seldom occur. Occasionally the pain in the stump is of a different nature and is more akin to a true causalgia such as is found after nerve injuries without amputation. In these cases the condition can only be cured by dividing the nerve at a considerably higher level.

Painful conditions of stumps are not invariably due to nerve involvement, sometimes there is a chronic periostitis of the end of the bone, perhaps with a sequestrum and a dormant focus of sepsis. Such a condition will be found by X-ray examination and can then be surgically treated. Occasionally a chronic inflammatory process around a non-absorbable ligature gives rise to painful nodules which should be removed.

An occasional complication of a painful stump is the occurrence of a constant twitching or shivering; it will generally be found when there is a painful nerve, which should be treated by crushing and ligature. The stump should then be immobilized for six weeks in plaster of Paris in order that it may rest completely. Most cases will be cured in this way.

TREATMENT OF UNHEALED STUMPS

In many of the amputations of war surgery the condition of the limb is such that it is impossible to secure primary union of the wound, at

Fig. 195.—The result of a guillotine amputation through the thigh, which has been left to heal by granulation without any secondary operation. There is a large terminal scar adherent to the bone.

least unless an unnecessary proportion of the limb is sacrificed. It is customary in this case to amputate either by the guillotine method, or with flaps which are turned back and left unsutured. These methods serve two useful purposes: they preserve as much as possible of the limb, and they secure good drainage of a septic wound; when such an amputation remains aseptic a secondary suture can be carried out. If the flaps are sufficient no further trimming is necessary; if they are insufficient a short additional piece of bone must be removed. Most of these amputations, however, become septic and early suture is then impossible

because necrosis of the end of the bone is almost certain to occur. In after-treatment the first essential is to prevent excessive retraction of the skin and muscles around the end of the stump; unless precautions are taken this is almost certain to occur. Extension upon the flaps should be carried out by means of a suitable splint; in the lower limb a splint consisting of a Thomas ring with side bars ending in a square frame which projects beyond the end of the stump is applied. Four extensions of strapping are fixed to the anterior, posterior, and lateral aspects of the stump and are tied below to a ring which fits inside this square frame.

FIG. 196.—Method of applying extension to the skin of an amputation stump which has not been sutured.

Extension is kept up by tying the ring to the frame. The whole of the end of the stump is left exposed and the dressing can be changed without interfering with the extension. A similar method may be adopted for amputations of the upper limb.

It is most important that stumps which have been treated in this way shall not be subjected to further re-amputations which shorten them more than is necessary; the second operation should be the final one if it is carried out in the right way and at the right time. It should result in rapid healing and in a stump which is at the best level and is most suitable for the application of an artificial limb, bearing in mind the initial level of the amputation. The chief fault in this second stage of treatment is excessive hurry in re-amputating; if possible any bare bone

in the end of the stump should be kept in view until a sequestrum has separated; if this is not possible this separation must be judged by X-ray appearances and by the time usually taken for the separation of sequestra in the particular bone affected. When necrosis is present the second operation should not be performed until after separation of the sequestrum, unless for other reasons it is desirable to shorten the stump considerably, either because there is insufficient skin to cover the bone or because the original amputation was at a bad level.

A second condition which must be present before further operation is carried out is the disappearance of œdema of the stump; this œdema is an indication that there is some infection in the tissues of the limb away from the end of the stump. These tissues must be divided in the process of re-amputation; if they are infected the new wound will be infected, therefore the operation should be postponed until there is no longer any risk of such infection and the clinical indication of this is the disappearance of the œdema.

The secondary operation upon a granulating stump will then be postponed until œdema has disappeared, and, if it is desirable to preserve the full length of the stump, until all sequestra have had time to separate. If, however, the original level of amputation is a bad one, or if an inch or two of bone can be sacrificed without affecting the functional result, time may be saved by performing a re-amputation without waiting for the separation of sequestra. In the former case the second operation will partake of the nature of a secondary suture, the sequestra being removed completely, the bone smoothed off if necessary, the scar tissue removed and the skin undercut and sutured with temporary drainage.

When a frank re-amputation is undertaken it is unnecessary to sacrifice much of the stump, all the healthy skin may be retained in the flaps, cutting close up to the margin of the new epithelium. The incision should then be deepened on to the bone just above the site of any bone which on skiagraphic evidence may be presumed to be infected, and the bone divided at this point. Throughout the operation it must be remembered that the granulating end of the stump and the end of the bone are infected, and that these must not be touched with any instrument or swab which is used in the freshly cut tissues. If these precautions be taken it will generally be possible to secure a clean wound which will heal by first intention. Of course, as in all amputations, it is desirable to drain the wound for forty-eight hours.

When a stump has healed except for the persistence of a sinus the treatment must depend upon the length of the stump and upon the condition of the skin and of the bone. When the amputation is at such a level that the sacrifice of an additional inch or two will not affect the functional result the most expeditious method of treatment may be

the performance of a re-amputation. This is particularly so if there are other defects in the stump such as the presence of extensive or adherent scars or of painful nerve ends. Re-amputation should then be carried out by the methods above described, a site being chosen in accordance with the advice as to length already given, the scars being excised,

FIGS. 197 and 198.—Amputation through the thigh with an ulcer in the centre of a large scar. There was also a terminal sequestrum enclosed in much new bone. The scar was excised, all sound skin being kept, just sufficient bone was removed to enable the flaps to meet. Fig. 198 shows the result three weeks after the operation. The patient was able to walk upon a temporary peg leg one week later.

if possible, and the nerve ends dealt with by crushing, ligature, and shortening. When, however, it is undesirable to shorten the stump the sinus must be dealt with upon the usual principles of treatment of any chronic sinus. If the scars are satisfactory and the sinus does not extend down to bone, it may be simply enlarged and curetted. Usually, however, a skiagraph will show the presence of one or more sequestra, and often

the scars will be such as to indicate the advisability of excising them. It is then best to excise the scars and whole sinus, removing new bone so that the end of the bone is clean and smooth. By this method we may be sure that no sequestrum is left, and a good sound stump may be

FIG. 199.—Ring sequestrum at end of stump, enclosed in much new bone.

obtained. Of course, it is often possible simply to enlarge the sinus and to extract one or more sequestra. But if this is done it is impossible to be quite sure that no more necrotic bone remains, and a badly scarred end is often left. Only in special cases in which a sequestrum is felt, and is not enclosed by bone, is such a simple procedure advisable, usually a more radical excision of scar tissue, and a complete cleansing of the bone end, is advisable.

SHRINKAGE OF AMPUTATION STUMPS

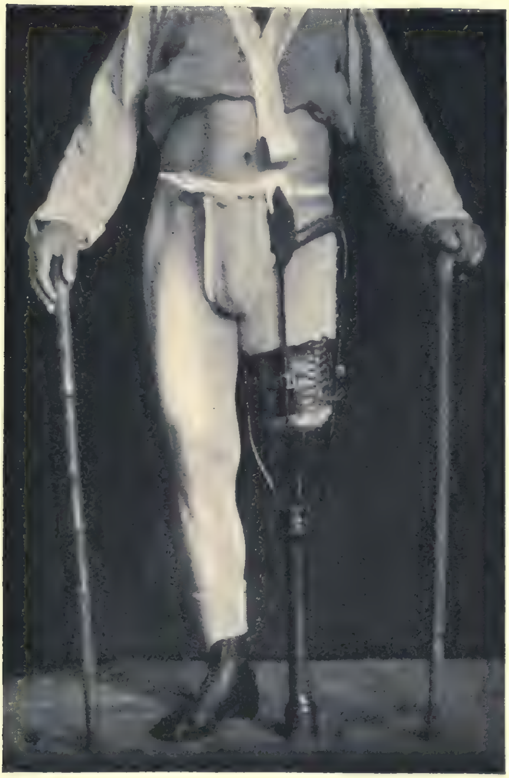
An amputation stump in the lower limb tends as a rule to shrink progressively for a considerable time. This results partly from the fact that the function of most of the muscles in the stump has disappeared, but this is not the whole cause. A considerable portion of the shrinkage results from the pressure of the bucket of the artificial leg. For this reason the mere passage of time is insufficient to secure shrinkage. It is often recommended that a stump should be left for some four to six months before the artificial limb is fitted, so that shrinkage may occur. This advice is bad, the limb should be fitted as early as possible, but as the renewal or alteration of a full artificial limb is expensive it is desirable in the first place to use a simple form of temporary peg leg, which can be easily replaced or altered. As it is the pressure of the stump in the bucket of this leg that will cause the shrinkage it is desirable that this temporary peg leg shall fit the stump as nearly as possible in the way in which the final leg will fit. That is to say, the bucket of the temporary leg should fit the whole stump accurately and should be specially made for the man. In the upper limb the stump does not tend to shrink after the artificial limb is fitted, if anything the use of the limb may tend to enlarge the stump by the hypertrophy of certain of the muscles as the result of use.

A second reason for the use of a temporary artificial leg at as early as possible a moment is that it is desirable to prevent the patient from getting into the habit of walking with crutches, and to secure functional use of the stump at an early stage. The use of the stump is the most certain method of preventing contractures of the proximal joints. In most cases a flexion contracture of the hip-joint in an amputation through the thigh may be traced to the fact that the patient has spent a long time in getting his stump healed, and has then been left without an artificial leg for a further period of months. Such contractures are best prevented by up-to-date methods of securing rapid healing of the stump and by fitting an artificial limb as soon as this healing is complete. In some cases it may be desirable to fit a temporary limb even before the stump has healed.

The simplest form of temporary artificial leg is that formed from a Thomas splint. A simple form of such appliance is shown in Figs. 200 and 201. The ring has attached to it four uprights instead of two; these end below the knee level in a metal collar into which the peg is fixed. The stump is kept in position by a leather band which buckles to the four uprights. The rings and uprights can be made in stock sizes and the peg adjusted for length in a few minutes. The harness consists of a simple suspender over the shoulders. This form of limb has the defect that it takes the weight entirely upon the ring and so does not help the shrinkage of the

stump. The best form of temporary leg is that in which the bucket is made of plaster of Paris. The leg shown in Fig. 202 is made in the following way.

The wooden framework is made of two crutch sticks attached at the lower end to a block of wood $2\frac{1}{2}$ in. in diameter. The crutch sticks are



FIGS. 200 and 201.—Front and back view of a temporary peg leg made on the pattern of a Thomas splint.

cut at the top so that when the end block is level with the heel of the boot of the sound leg the outer stick is level with the top of the great trochanter and the inner is about $1\frac{1}{2}$ in. below the perineum. The upper ends of the sticks are notched on the outer side so as to make them adhere in the plaster. Two small hooks are made of galvanized iron wire for insertion in the plaster.

The patient lies upon a hard table with a sandbag under the buttocks

and is made to press the stump backwards and inwards so that it is extended and adducted at the hip. A layer of stockinet is drawn up over the stump until it reaches above the tuberosity of the ischium posteriorly, to the perineum on the inner side and to the fold of the groin in front; at the end of the stump a circular pad of felt is applied and the stockinet is sewn over this. A plaster-of-Paris bandage is then applied

FIG. 202.—Temporary peg leg of plaster and wood.

to the stump, entirely enclosing it, reaching to within an inch of the perineum on the inner side, as high as the great trochanter on the outer side and up to or even above the tuberosity of the ischium at the back. The bandage should not be applied too tightly, but must be well moulded upon the stump. When it has partly set, the wooden frame is fitted into place, taking care that it lies parallel with the other limb. It is then fixed to the plaster bucket by applying additional bandages of plaster, and the two hooks are also included, on the inner and outer sides, about level with the lower end of the bucket. When the plaster has set, the

limb is removed and left to dry. The wooden crosspiece is then fixed below the bucket; this consists of a roller with a small groove upon which the chief sling can roll. The harness consists of a broad waist-belt, buckling in front and supported by a sling which passes over the opposite shoulder. To the lower end of the belt are attached in front three webbing bands. The central one of these carries a buckle, the other two carry rings. A fourth band of webbing is fixed to the back of the belt; this passes under the roller on the leg and is buckled to the middle band in front, the other two bands are attached to the hooks on the sides of the leg. These latter bands are interrupted by buckles so that they can be adjusted for length. In long stumps the mesial band and its hook can often be dispensed with. (This band is not shown in the illustration.)

A similar leg can be made for a below-knee amputation. The crutch sticks are fixed to a broader base block (4 in. in diameter). They are cut so as to end just below the head of the tibia and fibula, and are incorporated in the plaster bucket in exactly the same way. No roller or hooks are used, but instead two loops of wire are inserted on either side of the bucket about two inches below the level of the joint. The harness consists of a broad band of webbing which laces around the thigh just above the knee; from this are suspended four bands of webbing, two on the inner side, two on the outer side; each of these passes through the appropriate loop in the bucket and is buckled to the thigh band. The reason for the use of two bands on either side is that if one is placed in front and one behind the knee centre, one or other is always tight whether the knee is extended or flexed, and the leg does not tend to fall off.

For a Syme amputation an exactly similar leg is made except that the end of the stump is allowed to rest upon the base block, upon a felt pad, and the plaster case is only brought half-way down the calf; if the whole calf is enclosed, the leg will not be removable because the end of the stump is bulbous.

It is sometimes objected that the wearing of a temporary peg leg with a stiff knee-joint will induce bad habits of walking, the patient tending to carry the artificial leg away from the side in taking a step. In actual fact this is not found, and even were it to occur, it is a fault which is easily overcome and is more than counterbalanced by the education which the patient secures in balance upon the artificial leg, and by the fact that he gets his stump in good order and well shrunk before he gets his permanent artificial limb.

The shrinkage of stumps must be borne in mind whenever a patient who has been wearing a limb for a time comes under examination. If an artificial limb has been worn with comfort for some months and then either the limb or the stump gives trouble, it may be presumed that the fault lies with the fit of the limb, which is no longer accurate because of

the shrinkage of the stump. Thus such an alteration may give rise not only to loss of power to walk well, but also to actual friction on the stump which may cause ulceration or the formation of bursæ. The latter are particularly liable to arise over the head and tubercle of the tibia and over the head of the fibula in below-knee amputations, because the shrinkage of the soft parts leaves these bony points more prominent, and they become liable to friction. Excision of the bursæ will not put things right unless the artificial limb is also refitted.

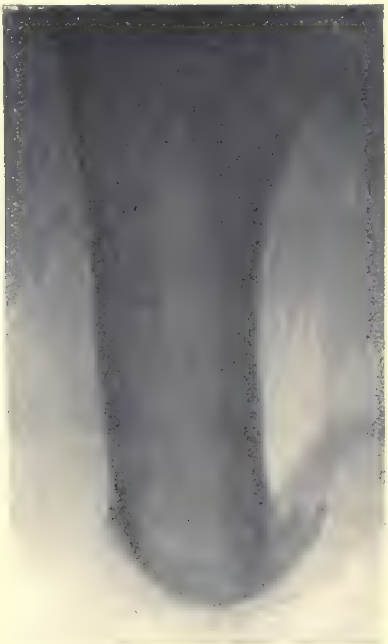


FIG. 203.—Large spur at the end of the bone in amputation through the thigh.

In many amputation stumps exostoses occur at the end of the bone. These are most common in thigh stumps where they are of two sorts. In one variety a diffuse exostosis occurs around the end of the bone, due probably to a septic osteitis. In the other a single spur arises from the end of the linea aspera and projects upwards; such a spur may be $1\frac{1}{2}$ or 2 in. long; it is probably an ossification in muscle, the result of stripped periosteum. Such spurs do not as a rule give trouble when an artificial limb is first fitted, but later when the stump shrinks they are no longer padded over by muscle and they may then be pressed upon by the bucket and become painful. If they give trouble in this way they must be removed. Occasionally such a spur may be painful because it is adherent to a scar, or even because it is adherent to or presses upon a nerve; in this case also it should be removed.

THE ORGANIZATION AND EQUIPMENT OF CENTRES FOR THE LIMBLESS

BY

Col. Sir JOHN LYNN-THOMAS, K.B.E., C.B., C.M.G.

THE ORGANIZATION AND EQUIPMENT OF CENTRES FOR THE LIMBLESS

In the days of peace before August 1914, there existed in our country no definite organization for dealing with the special problem of the limbless. Yet even then it was one of no small magnitude had we but realized the number of limbless men in the civilian population, how great was their handicap in the race of life, and the severity of the disability they suffered in earning a livelihood. A census taken recently in Wales of civilians who had lost a limb showed a ratio to population of over one in a thousand (1 in 810).[1] It may therefore safely be assumed that, as the population of the United Kingdom in the middle of 1914 was a little over 40,000,000, there were then in the British Isles some 40,000 persons who had lost a limb.

The war, even in its early days, caused a sudden increase in the number of limbless men, and there was presented to the mind a vivid picture of hundreds of maimed sailors and soldiers returning to their country to find that it possessed no institution to which they could go for help. This picture of youth crippled in the country's service made an instant appeal to the imagination, and a small band of men and women set to work to meet the situation.

Roehampton House, near Richmond Park, was opened in June 1915 as 'Queen Mary's Convalescent Auxiliary Hospital for Sailors and Soldiers who have lost their limbs in the War'. This institution made history in the theory and practice of reconstruction of the maimed, for it created and brought together a new team for working out the question of artificial limbs—the orthopædic surgeon, the limb-maker, the mechanical engineer, and the patient.

As the war went on the 'military limbless' problem rapidly increased in magnitude and importance, so that national sentiment was awakened to the fact that even Roehampton, with its hundreds of beds, was too small, and soon Scotland, Ireland, and Wales started their own Roehamptons; still, at the end of four years' war, it was found necessary to establish additional new limbless centres, and it is hoped that those who have to organize and administer them will find help in the following

[1] This census brought to light also the fact that though the ratio was highest in the industrial districts, where it was 1 in 690, it was still as high as 1 in 1,023 in rural areas.

notes founded on the lessons taught and the experience gained, whilst organizing in Cardiff a centre for Wales.

Many and complex are the problems to be solved at a limbless centre: they include the care, the reconstruction, and the re-education of the shattered man, as well as the treatment of his stump and the fitting of an artificial limb.

The governing idea of a limbless centre is to lead a man gradually from a state of helplessness to independence, enlisting his own interest and co-operation at every stage. It is not sufficient to order a man an artificial arm or leg. Each appliance, though many of its parts can be standardized, must be adapted to the particular case. The part of the limb in which amputation is performed depends on the nature of the injury, consequently the length of the stump varies. The artificial appliance must exactly fit the stump. This accurate fitting is not possible at once, for after the wound has healed a certain time must be allowed for the scars to become sound and firm, and for the changes which take place in the form of the stump to be completed. This period is utilized to improve the man's general health and to encourage him to learn to walk, or to use his amputated limb by exercising with a temporary appliance.

The practical value of a temporary appliance for walking has been fully demonstrated, and we have found the best type of temporary peg leg to be a modification of the Belgian pylon. Its plaster-bucket is fitted directly to the stump, and the whole can be applied and completed in from ten to thirty minutes, according to the site of amputation, whether below or immediately above the knee. Even when a pelvic band is required for amputation near the hip-joint, the time of application does not exceed thirty-five minutes. It is arranged that those who undertake to apply the modified Belgian pylons shall first be given an opportunity to see a practical demonstration of the method.

It is found even to-day that, in a high percentage of cases, the joint above the site of amputation has been allowed to get stiff in a faulty position during the period of healing. This is a serious handicap to the utility of an artificial limb and a great deal of specialized treatment may be required to restore normal articular movements. Examples of these crippling disabilities are common in the hip as flexion and abduction deformities, and can be detected by H. O. Thomas's method; in the shoulder they are evidenced by abduction and rotation deformities which hamper circumduction movements of the stump. These deformities can easily be prevented during the healing stage of an amputation, and it is highly desirable that those who perform the amputation should apply the methods of prevention by appropriate post-operative treatment. Until this recommendation is carried out in practice, it is imperative

that every artificial limb centre should have its own military orthopædic department, or an approved special surgical centre for the purpose.

When the artificial limb has been made it will probably require minor alterations to render it thoroughly comfortable, and the patient must be practised in its use until he is ready to go out into the world. A man with an artificial leg must learn how to walk with it up and down hill, on a sloping path, and on uneven ground; a man with an artificial arm must get practice in the use of tools, or of a pick and shovel, in the handling of farm implements, wheeling a barrow, forking hay, or lifting weights—all which things a man with a good well-fitting artificial arm can learn to do almost as well as an uninjured man.

Further, it must be remembered that an artificial limb will wear out or get broken, or out of order. The limb centre will be a place to which a pensioner can always come back to get his limb repaired, or adjusted, or to have a new one made if necessary.

Under the present conditions it is necessary for an artificial limb centre to have the following departments and resources:

(1) A military orthopædic centre or an approved special surgical centre.
(2) A hospital for the limbless, containing
(3) An artificial limb workshop.
(4) A parade hall.
(5) Recreation rooms.
(6) Training ground for artificial legs.
(7) Training ground for artificial arms.
(8) A technical school for vocational training.

1. **Military Orthopædic Centre.** At the orthopædic centre the patient undergoes such special surgical treatment, including operation, as may be necessary.

When a man who has lost a leg or both legs has reached a suitable stage of recovery, he is provided with a temporary peg leg; I prefer the pattern known as the Belgian pylon, which can be speedily made up from standard material and a plaster-of-Paris bandage.

At the Prince of Wales's Hospital, Cardiff, the patients when admitted are all wearing these pylons; they parade each morning, and go over the same ground as men with artificial limbs. As soon as a man is fitted with an artificial limb (in the rough) he is taken to the parade hall, described below, and instructed how to walk between the barriers for half an hour two or three times a day. On the second day he is taught to walk in the parade hall with a stick only, and on the third day is taken out into the grounds and over the special training ground. The men naturally require a little help the first morning, but after that they go alone. After this

test they are taken back to the parade hall, and each man is asked if he has any complaints to make as to his artificial limb ; if he has the limb-maker is called for ; the complaints reported to him, and he is asked to carry out the alterations at once so that the man may be on parade next day. Usually the men wear their legs in the rough for six days, or until they pronounce that they are perfectly comfortable and are walking to the satisfaction of the instructor. The limb is then sent back to the workshop to be finished, the man meanwhile going back to his pylon, but coming on parade each morning as usual. When the limb is completed and returned to him he wears it on parade again for eight days. He then goes before the consulting surgeons to be passed out with it. A man who has lost an arm is in the same way provided with a temporary arm, a new appliance invented since the outbreak of war. When the permanent artificial arm is ready to be worn, the man is trained in its use by a patient who was fitted with an artificial arm in 1917 at this hospital.

2. **A Hospital for the Limbless.** A hospital for limbless men must, of course, be constructed on sound architectural lines with regard to sun, light, and air, but particular attention has to be given to certain special requirements. The governing idea is to let a man live under conditions which will prevail when he goes to his own home. It is unnecessary and unwise to provide lifts in the hospital.

The *ground floor* of the hospital should be considered from the point of view of men who have lost both legs, and must therefore use a wheel chair until they have been successfully fitted. The main building must, therefore, be entered not by steps, but by an inclined plane (1 in 24), up and down which a man can take himself in a hand-propelled wheel chair. If he has lost both his legs he must find his ward, with bathroom and lavatory attached, on the ground floor. The dining-room and recreation-room should also be on this floor, and another inclined plane should lead him from the recreation or dining-room into the garden. Under these conditions the most badly crippled man enjoys from the first a certain amount of independence. Special attention should be paid to the following details :

(a) *Beds.*—The best type of bed is a high one—30 in.—as it makes it easier for the man to get into his artificial legs.

(b) *Baths.*—The best type of bath is the old-fashioned bath with a wooden seat all round. It is easier and safer for the patient to get into such a bath than into one of modern type. For double amputations the bath must be low and not too deep nor too wide. The men should be encouraged to get into their baths by themselves. They like to feel independent as early as possible, and this small matter helps them. It brightens their outlook.

(c) *Lavatory.*—Special fixed nailbrushes should be provided. Mirrors on the wall must be low for the wheel-chair men. A long vertical mirror will suit all heights and conditions.

(d) *Windows.*—The bottom sash of the window must be low and easy to open by emergency bolts in case of fire. If the windows are of what is commonly called the French pattern, they must for the same reason be made easy to open.

(e) *Staircases.*—Each stair should be six inches high and one foot in depth. The stairs should be covered with rubber matting. Two hand-rails are required.

The *first floor* of the hospital should be organized on the same principles as the ground floor, and efficient fire-escapes provided. This floor should be occupied by the one-legged men. The armless men may occupy the second or third floors.

3. **Artificial Limb Workshops.** The importance of having workshops on the spot is very great. It will be readily understood that in finally fitting an artificial limb, so that it may be thoroughly comfortable and useful, many small alterations and adjustments will be necessary, and in making these the man's own feelings must be consulted and his advice accepted. No officer or man should be discharged from the hospital until he pronounces his limb comfortable and has gained confidence in its use.

It is not within the scope of this chapter to discuss the materials used in making artificial limbs, but it may not be out of place to note that a great variety of leather and wood is used. In the construction of artificial legs, the upper socket of a below-knee leg is blocked sole leather, whilst the wood portions are covered with raw hide. All straps that take any strain are cut from bridle butt. The wood used for the main portions of a limb is willow, strengthened at vital spots with beech and birch ; the latter woods are too heavy to be used throughout. We have found that the knee-joint in an artificial leg should be set at right angles to the patient's line of progress ; it should not be rotated in or out. It should be truly horizontal and the knee centre should never be lower than that of the sound limb—with tall men it is sometimes an advantage to have it an inch higher.

4. **Parade Hall.** When a man first wears his new leg he is taken to the parade hall, a long room, with terrazzo floor and two sets of parallel bars to suit men of different heights. The bars give him confidence, and at the far end are mirrors so that he can see for himself any error he may make in his first attempt to walk, and is shown by an instructor how to correct it.

In the case of a man who has been so unfortunate as to lose both legs, the problem is naturally more difficult to solve, and a longer preliminary stage is necessary to restore his confidence in himself. Hitherto,

these poor fellows, in order to get into their artificial legs, have had to depend on two people to lift and steady them. This difficulty has been overcome by a special appliance consisting of pulleys and tackle, an 'aerial transporter crutch' (see Fig. 204), by which the man can lift himself from his wheel chair into his artificial limbs and allow just so much of his weight to rest upon them as he feels he can bear. Gradually, guided by his own sensations, he bears more and more weight until he finds he can stand, and finally begins to walk. The man who has lost only one leg, of course, makes more rapid progress, and, from the parade hall, with its parallel bars, soon passes on to practise walking in the garden. It is important that the artificial leg should be of exactly the right length for comfort.

FIG. 204.

There is some difference of opinion among surgeons as to what this length should be. Some prefer the artificial leg to be the same length as the sound leg, their reason being that when the stump shrinks the patient sinks farther into the leg and the limb will not be unduly short. Others prefer the artificial leg to be a quarter of an inch shorter than the sound, because they find that when a man commences walking with both legs the same length he develops an awkward gait, the artificial foot being moved out instead of forward to clear the ground; once a patient gets this habit it is almost impossible to eradicate it.

In deciding this point, the man's own feeling is the best guide, and much assistance may be obtained by the simple plan of placing boards of various thickness (1, $\frac{5}{8}$, and $\frac{1}{4}$-inch boards are the most useful) on the floor of the parade hall. The man walks with the sound foot on the floor and the artificial on one board after the other until he makes up his mind which is the best: the artificial leg is then lengthened or shortened accordingly.

5. **Recreation Rooms.** A recreation hall is a very essential part of the treatment of limbless men. It is most important, with a view to their

restoration, to encourage them to play games and to become interested. Billiards is a splendid stimulus for both the armless and the legless men.

6. **Training Ground for Artificial Legs.** Experience has shown that it is very necessary to have arrangements for the testing of an artificial leg in actual use, and for the training of the man until he gets accustomed to the variations in the pitch of roads and paths which pass almost unnoticed by a man with two sound legs. This was illustrated by the case of a collier-soldier who had been fitted with an ingenious artificial leg at another hospital, where training in its use was carried out only on level ground. He applied to the Prince of Wales's Hospital, Cardiff,

FIG. 205.

to be provided with a peg leg instead ; his story was that, when he got home to Wales, very proud of his new leg, his father, who had lost a leg in a mining accident, challenged the son to a race up the steep side of a hill on which he lived. The father won easily, and then explained to his son that he felt sure of success because he had gained experience in the use of a complicated leg on a hillside. This incident shows the necessity of creating a training ground to enable men with artificial limbs to meet the natural conditions under which they have to live. The garden of the limbless centre for Wales has been planned with this end in view (Fig. 205). It is a miniature 'Wild Wales', laid out with much skill to imitate the conditions existing in a land of hills and dales. It has rough stone paths, some on the level, and others presenting gradients varying in pitch up to 1 in $3\frac{1}{2}$; moreover, the paths are laid so that as the man walks, the right foot is in one stretch higher than the left, and in another the left higher than the right.

Fig. 206.—Training-ground for artificial arms.

7. **Training-ground for Artificial Arms** (Fig. 206). The department for artificial arms is arranged for training the men in their use,[1] and also for testing the strength and suitability of the appliances. It is provided with spring balances to record the power of lifting, pushing, or pulling, and apparatus for measuring the breaking strain of steel wires, thongs, and ropes used in the construction of limbs.

8. **Vocational Training.** Special arrangements should be made with the disablement committees of the Ministry of Pensions in the area from which the soldier comes or is intending to make his home.

Experimental Workshops.

Since new problems must be expected constantly to arise for solution, an experimental workshop should be established to deal with new inventions and designs for artificial limbs for the upper and the lower extremities. The value of such inventions must be thoroughly tested under skilled supervision. For this purpose, two testing departments have been established at the Welsh centre, the one for inventions designed for the lower extremity, the other for those for the upper extremity. The strength of materials should also be tested here before they are worked up.

APPENDIX

WEIGHT OF NATURAL AND ARTIFICIAL LIMBS

The following information was obtained from Professor A. Keith, F.R.S. :

The total weight of a lower extremity was found to be 18·6 per cent. of the body weight.

The total weight of an upper extremity was found to be 6·38 per cent. of the body weight.

If you take an 11 stone man (154 lb.), a lower extremity would be 28·65 lb., made up thus :

Thigh	11·6	per cent. of	body weight		17·85 lb.
Leg	5·2	,,	,,	,,	8·9 ,,
Foot	1·8	,,	,,	,,	2·8 ,,
	18·6	,,	,,	,,	28·65 ,,

An upper extremity would be 9·8 lb., made up thus :

Upper arm	3·3	per cent.	body weight		5·1 lb.
Forearm	2·28	,,	,,	,,	3·5 ,,
Hand	·8	,,	,,	,,	1·2 ,,
	6·38	,,	,,	,,	9·8 ,,

The weights of the standardized artificial limbs made for the patients at the Prince of Wales's Hospital are given for comparison.

[1] It has a sand-pit for practice with shovels, spades, mattocks, and rakes; wood-blocks for the use of axes and hammers; an up-and-down path for wheeling a barrow.

LOWER LIMB

For disarticulation at the hip (including tilting table)	9 lb.
For amputation through the upper thigh (with pelvic band)	7¼ ,,
For amputation through the middle thigh	6½ ,,
For amputation through the knee	6 ,,
For amputation below the knee	5¾ ,,
For Syme's amputation	3½ ,,

UPPER LIMB

For disarticulation at the shoulder	3 lb. 10¼ oz.
For amputation above elbow	2 ,, 12½ ,,
For amputation below elbow	2 ,, 4½ ,,
For amputation of the hand	7½ ,,

END OF VOL. I

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